CHAPTER 3

TRIP GENERATION AND PERSONAL MOBILITY

3.1 Trip Generation Analysis

Travel demand is closely related to socio-economic level and land-use of the area. To this end, the analysis of trip generation is directed to the formulation of mathematical models governing the relationship between the number of trips being made by a household and its socio-economic activities such as family size and income, vehicle ownership, etc. In this study, multiple linear regression and category analyses were presented to formulate such relationship.

3.1.1 Multiple linear regression analysis

Multiple linear regression analysis is a statistic technique applicable to the estimation of a response variable or dependent variable for various levels of one or more independent variables. In trip generation analysis, it is often used to estimate amount of trips generated in response to one or more socio-economic factors such as level of household income and vehicle ownership. In this study, seven household characteristics are selected as the independent variables. There are number of persons per household (X_1), number of persons 7 years of age and older (X_2), number of family workers (X_3), family income in baht per year (X_4), number of pupils per household (X_5), number of bicycle owned (X_6), and number of motorcycle owned (X_7). The amount of trips denoted as dependent variable (Y) is taken to be the home-based trips per household per month.

Then, the following equation is formed to obtain
total home-based trips estimates:-

$$Y = b_0 + b_1X_1 + b_2X_2 + - - - - - - + b_7X_7$$

where b_0 to b_7 are the coefficients of the respective
independent variables to be estimated.

The above independent variables can be grouped into
3 major household characteristics i.e. (i) family size, (ii) bicycle
& motorcycle ownership and (iii) family income, which are to be in-
vestigated the relation to the frequency of the home-based trips.

(i). Family size. Four hundred households in the
study area were grouped in accordance to the number of persons in
household. A mean trip generation rate was then computed for each
household size which is summarized in Table 3.1 and shown in Fig.3.1.
It can be seen from the figure that home-based trips increases as
number of persons per household increases. Table 3.2 and Fig. 3.2
show that the work trip and non-work trip increase with an increasing
number of persons 7 years of age and older in the family. This is
due to the number of persons 7 years of age and older include both
of the number of pupils per household and the family workers.
Considering on the number of pupils and the family workers seper-
ately, it was found that increase in number of pupils in the family
tends to increase the non-work trip rate whereas work trip rate is
not disturbed as summarized in Table 3.3 and showed in Fig. 3.3.
Similary, work trip generation rate increases with an increasing
of the number of family workers whereas the non-work trip rate
remain at the same level as illustrated in Table 3.4 and appeared
in Fig. 3.4. Regardless of types of people in a household, the
increase of family size is to increase the monthly rate of home-
based trips as appeared in Fig. 3.1.

Table 3.1 Frequency of Home – Based Trip , Work Trip and Non – Work Trip Classified by Number of Persons per Household

Number of persons per household	Number of households	Average monthly trip/household		
		Home – based trip	Work trip	Non – work trip
1	5	11.16	4.58	6.58
2	18	24.51	11.26	13.25
3	54	36.25	18.30	17.95
4	84	42.39	17.97	24.42
5	64	58.15	25.47	32.68
6	63	67.26	24.74	42.52
7	44	86.22	33.11	53.11
8	30	80.42	30.78	49.64
9 & over	38	101.75	39.66	62.09
Total average		60.12	24.50	35.62

Fig. 3.1 Relationship Between Household Size and Home – Based Trip , Work Trip and Non – Work Trip
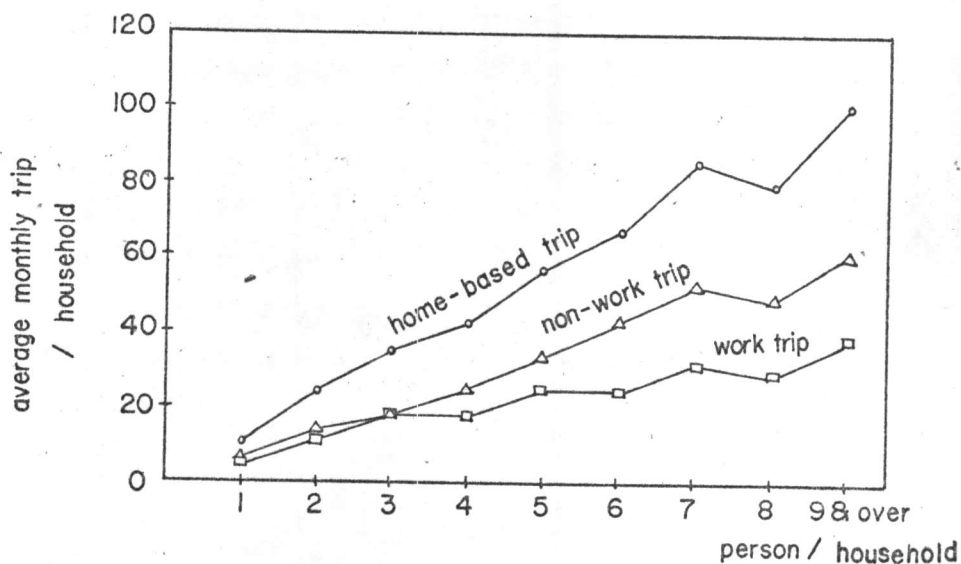
Table 3.2   Frequency of Home – Based Trip, Work Trip and Non – Work Trip Classified by Number of Persons 7 Years of Age and Older per Household

No. of persons 7 years of age and older per household	Number of households	Average monthly trip / household		
		Home – based trip	Work trip	Non – work trip
1 – 2	58	24.51	12.58	11.93
3	66	38.15	17.11	21.04
4	85	53.14	21.52	31.62
5	61	65.18	26.89	38.29
6	53	78.93	30.26	48.67
7 & over	77	96.51	37.24	59.27
Total average		60.12	24.50	35.62

Fig. 3.2   Relationship Between Number of Persons 7 Years of Age and Older per Household and Home – Based Trip, Work Trip and Non – Work Trip
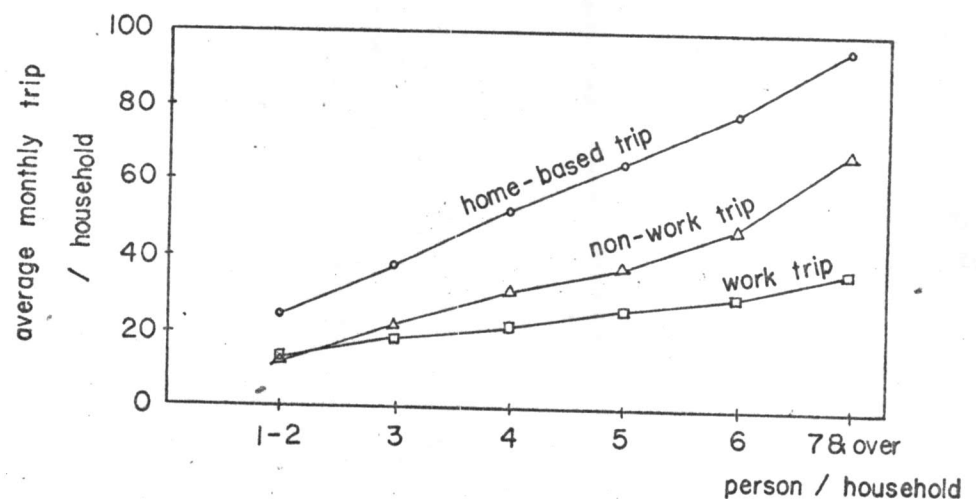
Table 3.3. Frequency of Home—Based Trip, Work Trip and Non—Work
Trip Classified by Number of Pupils per Household

Number of pupils per household	Number of households	Average monthly trip / household		
		Home—based trip	Work trip	Non—work trip
0	143	38.20	22.68	15.52
1	106	56.64	25.23	31.41
2	84	73.79	25.84	47.97
3	45	87.55	27.96	59.59
4 & over	22	110.01	20.70	90.31
Total average		60.12	24.50	35.62

Fig. 3.3 Relationship Between Number of Pupils per Household and
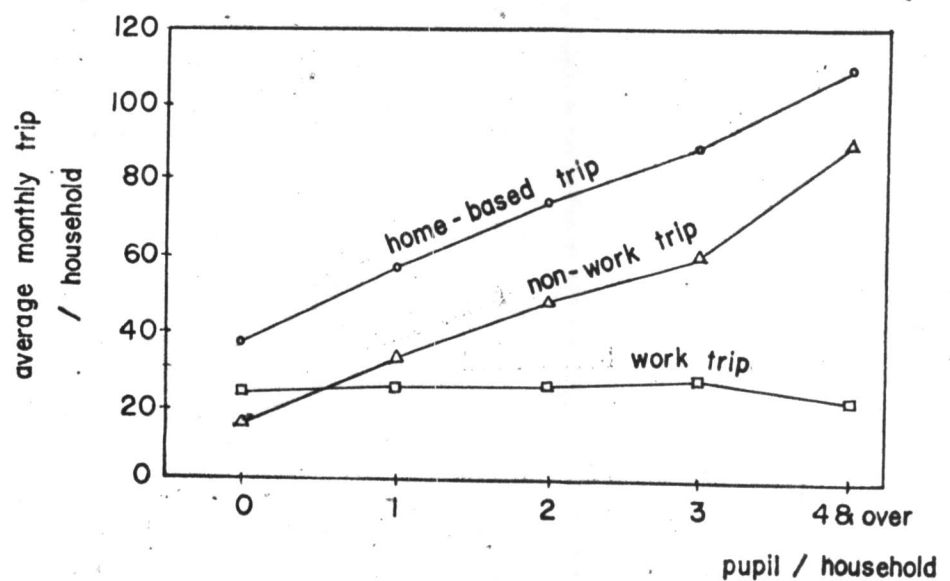Home—Based Trip, Work Trip and Non—Work Trip

Table 3.4 Frequency of Home — Based Trip, Work Trip and Non — Work Trip Classified by Number of Family Workers per Household

Number of family worker per household	Number of households	Average monthly trip / household		
		Home-based trip	Work trip	Non-work trip
0-1	49	38.64	5.78	32.86
2	131	48.92	18.38	30.54
3	85	68.08	28.17	39.91
4 & over	135	73.77	34.92	38.85
Total average		60.12	24.54	35.62

Fig. 3.4 Relationship Between Number of Family Workers per Household and Home— Based Trip, Work Trip and Non — Work Trip
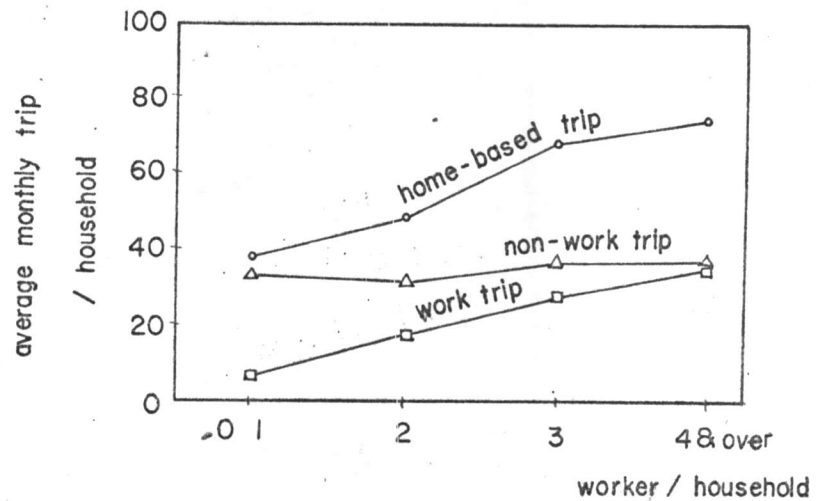
(ii). Bicycle & motorcycle ownership. Earlier studies have reported impressively high correlation between mean trip generation rate and average car ownership. Due to a few cars in the study area, in this study, the term car ownership will be represented by bicycle & motorcycle ownership. Table 3.4 shows the bicycle & motorcycle ownership per household in the study area. It was found that Tambon Tak Ok and Tambon Tak Tok had the highest rate of bicycle & motorcycle ownership, respectively. Categorizing 400 households in the study area according to the number of bicycle & motorcycle ownership, the average home-based trip were then computed for each level of bicycle & motorcycle ownership. These data summarized in Table 3.6. This indicated that the home-based trip per household increased with an increasing number of bicycle & motorcycle per household.

(iii). Family income. Family income is one of the major determinants of the level of family enjoys. As such, family income should be associated with trip frequency, as well as, other household characteristics (such as household size) which have been shown to effect trip generation rates. To examine the relationship between family income and trip generation rate, the family income in the study area were classified into six categories. The household in the study area were then identified with one of the six categories according to the reported family income. Average home-based trip rates were computed for each of these six categories and are reported in Table 3.7 and shown in Fig. 3.5. It was found that average home-based trips increase with an increasing of family income. The sharp dip at the family income ฿ 25,000-35,000 category is probable due to high percent of merchant (43 percent) in this category as indicated in Table 2.12. It is the business characteristic of the area that merchant families always do their business at home.

Table 3.5 Rate of Bicycle and Motorcycle Ownership
         per Household

Tambon	Vehicle ownership	
	Bicycle	Motorcycle
Tak Ok	1.19	0.32
Mae Salit	0.52	0.10
Samo Khon	0.78	0.05
Ko Taphao	0.59	0.25
Tak Tok	0.94	0.38
Thung Kracho	0.57	0.17
Thong Fa	0.31	0.04
Amphoe Ban Tak	0.71	0.20

Table 3.6 Average Home-Based Trip per Household at Various Levels
          of Bicycle & Motorcycle Ownership

Number of bicycle per household	Number of motorcycle per household			
	0	1	2 & over	Total
0	51.18* (156)**	62.17 (11)	81.83 (2)	52.26 (169)
1	58.91 (148)	71.47 (38)	85.08 (1)	61.61 (187)
2 & over	82.66 (27)	80.36 (13)	104.70 (4)	83.98 (44)
Total	57.20 (331)	71.68 (62)	95.36 (7)	60.12 (400)

* 51.18 = frequency of home-based trips per household

** (156) = number of households sample

Table 3.7 Frequency of Home–Based Trip, Work Trip and Non–Work Trip Classified by Family Income Levels

Family income level (baht / year)	Number of households	Average monthly trip / household		
		Home–based trip	Work trip	Non–work trip
∠ 5000	100	45.56	21.54	24.02
5001 — 15000	186	60.55	25.91	34.64
15001 — 25000	65	72.84	23.89	48.95
25001 — 35000	16	57.46	20.47	36.99
35001 — 45000	18	75.30	21.88	53.42
≥ 45001	15	81.31	36.80	44.51
Total average		60.12	24.50	35.62

Fig. 3.5 Relationship Between Family Income Levels and Home–Based Trip, Work Trip and Non–Work Trip
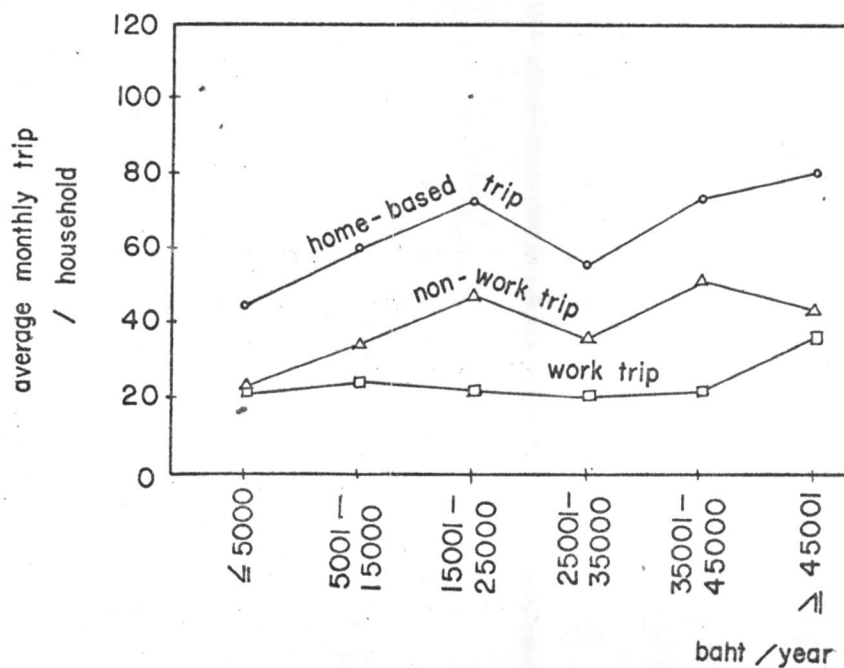
A computer programe for the regression analysis at the Department of Computer Engineering, Faculty of Engineering, Chulalongkorn University was used to estimate all coefficients of the independent variables.

Changing of the array of independent variables by adding or withdrawing were performed in order to find the acceptable equation. The accepted equation for the final selection must have a high value of the coefficient of multiple determination (R^2), the low value of the standard error of estimate (SEE), a resonable sign for the coefficient of each independent variable, and a high "t" value for measure of the level of significant.

By household data, seperated multiple linear regression equations were then analysed for each Tambon. Having completed the analysis of those regression equations, the regression equation for the whole study area was also computed. The selected equations were summarized in Table 3.8. Because of similarity in the socio-economic activities of Tambons in the study area, thus, the same set of independent variables appears in the regression equation for each Tambon. It is clear that the family income significantly related to home-based trip generation rates only in Tambon Tak Ok and Tambon Tak Tok. This is due to the fact that Tambon Tak Ok is the central business district of the area and Tambon Tak Tok is the highest family income level as indicated in Table 2.10. The independent variables that play most significant effect to the home-based trip generation rates are the number of persons 7 years of age and older and the number of pupils in the family.

Other equations were shown in Appendix.

Table 3.8 The Acceptaple Multiple Regression Equations of Each Tambon and of Amphoe Ban Tak

| | Tambon | | | | | | | | | | | | | | Amphoe | |
| | Tak Ok | | Mae Salit | | Samo Khon | | Ko Taphao | | Tak Tok | | Thung Kracho | | Thong Fa | | Ban Tak | |
	coef.	"t"	coef.	"t"	coef.	"t"	coef.	"t"	coef.	"t"	coef.	"t"	coef.	"t"	coef.	"t"
b_0	-15.46	1.92	15.00	2.23	6.73	1.59	13.47	2.38	-10.91	1.66	11.83	2.07	10.80	2.12	7.62	3.36
b_1	—	—	—	—	—	—	—	—	—	—	6.44	5.57	—	—	—	—
b_2	15.38	9.83	7.11	5.11	9.32	7.59	8.39	5.45	13.30	11.11	—	—	7.77	6.35	6.44	5.40
b_3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.11	2.62
b_4	0.0006	3.07	—	—	—	—	—	—	0.0003	2.20	—	—	—	—	—	—
b_5	—	—	12.50	5.15	6.95	4.00	7.02	3.15	—	—	8.16	4.59	8.32	3.07	10.23	7.76
b_6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
b_7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
SEE	20.28		16.62		13.61		15.73		20.01		14.84		13.52		16.91	
R^2	0.72		0.67		0.79		0.70		0.68		0.70		0.72		0.69	
L.S.*	10%		5%		20%		5%		20%		5%		5%		1%	
Number of sample	53		50		58		63		65		60		51		400	

* Level of significance

3.1.2 Category analysis

An alternate method to the analysis of trip generation by regression analysis is Category analysis. With the same concept previously taken, it is a simple technique to estimate the trip generation rate based upon the household characteristics. Informations pertaining to households were sorted into a number of seperate categories according to a set of variables which characterize the household economics activities for example income level and vehicle ownership. In this study, family income, household size and number of family workers were selected as the set of variables. For each income range, a trip rate was calculated for each household category classified by household size and number of employed person in a household as shown in Table 3.9. The Table shows the result of the category analysis of trip generation in the study area. Each cell which represents one household category contains informations on number of trip generated, number of household mean and standard error of the trip generation rate for that household category. Figures as contained in Table 3.9 may be translated easily into a number of trip generation by the following equation:—

$$p = \sum h(c) t_p(c)$$

where 　　p　　=　the number of trip generation

　　　　$h(c)$　=　the number of households in category c

　　　　$t_p(c)$=　the average trip generation rate of household in category c

　　　　$\sum$　=　represents the summation over categories.

Table 3.9 Trip Generation Category Analysis

Family income 5,000 baht/year and under

Number of family workers per household	Home-based monthly trip per household					Total
	Household size					
	1-2	3-4	5-6	7-8	9&over	
0-1	96^a 5^b 19.20^c 4.46^d	296 10 29.60 5.69	–	59 1 59.00 –	–	451 16 28.19 4.43
2	188 8 23.50 2.44	437 16 27.31 2.24	402 8 50.25 7.12	–	–	1027 32 32.09 2.83
3	–	282 8 35.25 5.45	399 6 66.50 7.90	518 7 74.00 7.81	–	1199 21 57.10 11.45
4 & over	–	131 3 43.67 3.21	659 14 47.07 3.82	675 9 75.00 8.30	414 5 82.80 11.77	1879 31 60.61 9.84
Total average	284 13 21.85 2.25	1146 37 30.97 2.24	1460 28 52.14 3.45	1252 17 73.65 5.33	414 5 82.80 11.77	4556 100 45.56 2.54

a   Trip generation of household in category

b   Number of household in category

c   Mean trip generation rate per household in category

d   Standard error of the mean

Table 3.9 Trip Generation Category Analysis (cont.)

Family income 5,001-15,000 baht/year

Number of family workers per household	Home-based monthly trip per household					Total
	Household size					
	1-2	3-4	5-6	7-8	9&over	
0-1	87	155	44	73	-	359
	5	7	1	1		14
	17.40	22.14	44.00	73.00		25.64
	5.08	4.41	-	-		4.89
2	73	1532	1426	250	65	3346
	3	35	23	3	1	65
	24.33	43.77	62.00	83.33	65.00	51.48
	2.75	2.56	4.13	17.24	-	2.61
3	-	797	738	593	93	2221
		16	11	7	1	35
		49.81	67.09	84.71	93.00	63.46
		4.17	3.91	6.61	-	3.53
4 & over	-	239	1808	1758	1531	5336
		5	29	22	16	72
		47.80	62.35	79.91	95.69	74.11
		3.13	3.96	4.53	4.26	2.87
Total average	160	2723	4016	2674	1689	11262
	8	63	64	33	18	186
	20.00	43.22	62.75	81.03	93.83	60.55
	3.40	2.10	2.42	3.55	4.03	1.91

Table 3.9 Trip Generation Category Analysis (cont.)

Family income 15,001-25,000 baht/year

| Number of family workers per household | Home-based monthly trip per household | | | | | Total |
| | Household size | | | | | |
	1-2	3-4	5-6	7-8	9&over	
0-1	—	281 7 40.14 5.65	152 2 76.00 26.96	258 3 85.87 8.39	—	691 12 57.54 7.99
2	—	321 8 40.13 5.69	281 4 70.25 19.32	—	304 2 152.00 4.42	906 14 64.71 12.05
3	—	412 8 51.50 7.74	408 6 68.00 12.84	302 3 100.67 8.28	322 3 107.33 3.76	1444 20 72.20 6.97
4 & over	—	—	241 4 60.25 11.60	775 8 96.88 6.04	678 7 96.86 6.22	1694 19 89.16 5.27
Total average	—	1014 23 44.09 3.77	1082 16 67.63 7.17	1335 14 95.36 4.23	1304 12 108.67 6.98	4735 65 72.84 4.15

Table 3.9 Trip Generation Category Analysis (cont.)

Family income 25,001 baht/year and over

Number of family workers per household	Home-based monthly trip per household					Total
	Household size					
	1-2	3-4	5-6	7-8	9 & over	
0-1	21 1 21.00 --	111 3 37.00 13.76	173 2 86.50 15.67	88 1 88.00 --		393 7 56.14 12.76
2	32 1 32.00 --	437 11 39.73 7.67	382 6 63.67 5.21	146 1 146.00 --	132 1 132.00 --	1129 20 56.45 8.11
3	-- 	-- 	488 5 97.60 15.15	271 3 90.33 15.45	164 1 164.00 --	923 9 102.56 11.98
4 & over	-- 	87 1 87.00 --	358 6 59.67 9.15	440 5 88.00 7.82	164 1 164.00 --	1049 13 80.69 9.35
Total average	53 2 26.50 5.42	635 15 42.33 6.82	1401 19 73.74 6.26	945 10 94.50 7.89	460 3 153.33 10.52	3494 49 71.31 5.53

3.2 Personal Mobility Analysis

Mobility means "capable of moving". Thus, personal mobility is referred to capable of personal movement. It is understood that capable of personal movement is mainly reflected by the frequency of travel, travel speed and modes of travel. To this end, personal movement magnitude of individual Tambons in the study area are not at the same levels. It could be measured in a relative term by setting up a mathematic expression which is a function of mode of travel, frequency of travel during a period of time and trip length. In order to set up the function which measures personal mobility, it deems necessary that characteristics of travel in connection with personal mobility namely frequency of travel by various modes and trip length be investigated.

3.2.1 Frequency of travel by various modes

Mode of travel was classified into six categories- walking, bicycle, motorcycle, local bus, long haul bus (travelling between Changwads) and other (included-car, car passenger, boat). The distribution of home-based trips per household by various modes of travel in the study area are summarized in Table 3.10 and Fig.3.6. Due to the low economic level in the study area, a walking trip is the dominant mode of travel which accounts about 65 percent of total travel by all modes. The next important mode of travel are bicycle and local bus modes.

3.2.2 Trip length

For each Tambon, average trip length on each mode of travel was calculated and shown in Table 3.11. Regardless of modes of travel, the average trip lengths for two purposes of travel in

Table 3.10 Distribution of Home–Based Monthly Trip per Household by Various Modes of Travel

| Tambon | Home–based monthly trip per household | | | | | | Total |
| | Mode of travel | | | | | | |
	Walking	Bicycle	Motorcycle	Local bus	Long hual bus	Other	
Tak Ok	34.88	17.87	7.46	8.72	0.39	0.64	69.96
Mae Salit	45.63	4.00	1.66	10.28	0.08	1.38	63.03
Samo Khon	35.60	8.65	0.48	7.42	0.33	1.35	53.83
Ko Taphao	41.81	5.80	4.40	7.03	0.38	1.20	60.62
Tak Tok	29.68	10.27	7.48	7.81	0.47	0.63	56.34
Thung Kracho	44.20	5.49	1.67	8.81	0.09	0.68	60.94
Thong Fa	46.16	4.44	0.12	6.15	0.02	0.51	57.40
Amphoe Ban Tak	39.41	8.10	3.44	8.00	0.26	0.91	60.12

Fig. 3.6   Number of Trips by Various Modes of Travel of
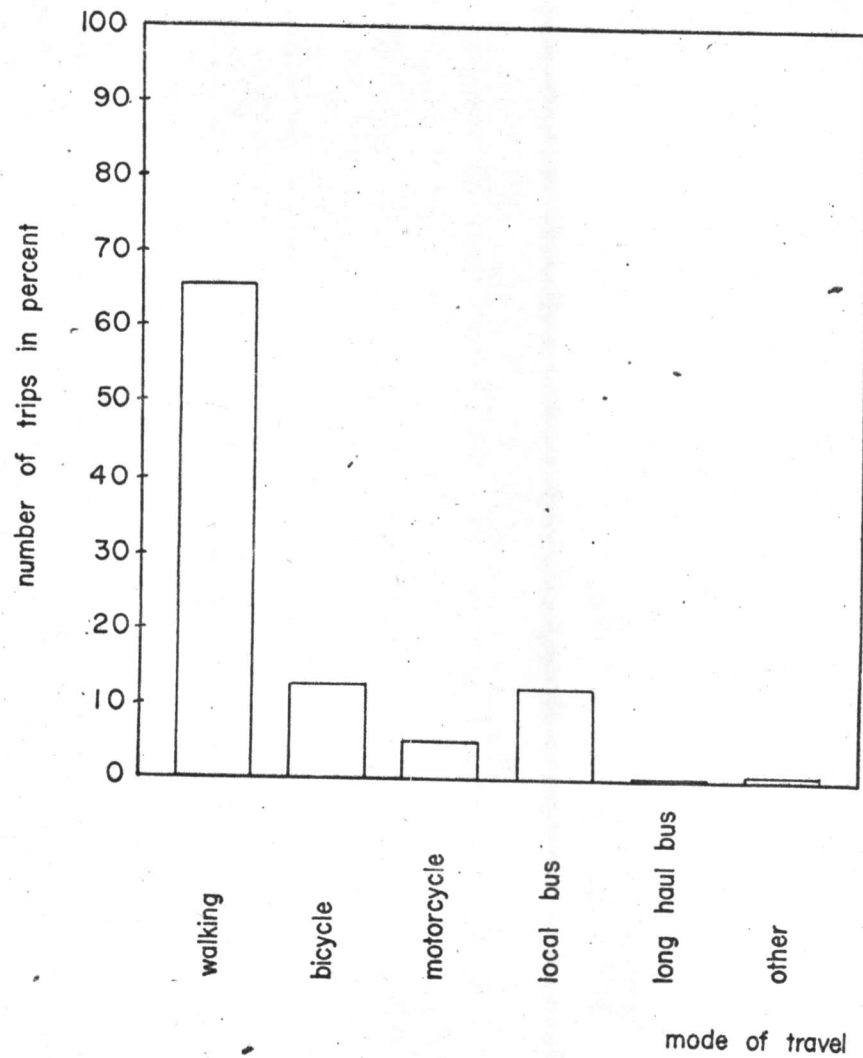the Household in Percent

Table 3.11 Distribution of Trip Length for Various Modes of Travel

| Tambon | Trip length (km.) | | | | | |
| | Mode of travel | | | | | |
	Walking	Bicycle	Motorcycle	Local bus	Long hual bus	Other
Tak Ok	1.61	1.78	7.04	19.61	313.13	98.63
Hae Salit	1.50	1.38	5.46	20.87	174.77	13.85
Samo Khon	0.95	3.02	15.66	15.64	243.53	17.73
Ko Taphao	1.37	3.17	5.62	23.26	343.91	17.78
Tak Tok	1.21	2.92	9.67	19.98	242.61	21.50
Thung Kracho	1.47	1.43	10.07	24.28	216.11	29.76
Thong Fa	1.29	1.67	13.49	25.03	532.80	30.07
Amphoe Ban Tak	1.35	2.30	8.01	21.13	278.35	27.81

Table 3.12 Average Trip Length for Home-Based Trip, Work
Trip and Non-Work Trip

Tambon	Trip Length (km.)		
	Home-based trip	Work trip	Non-work trip
Tak Ok	7.11	4.32	8.42
Mae Salit	5.24	2.59	8.42
Samo Khon	5.36	3.63	6.36
Ko Taphao	6.85	3.59	9.10
Tak Tok	7.50	5.88	8.37
Thung Kracho	5.63	2.36	7.90
Thong Fa	4.36	2.26	6.35
Amphoe Ban Tak	6.09	3.42	7.93

Table 3.13   Percent of Trip Length More Than That Shown Km.
of Work Trip and Non-Work Trip

Trip length more than km.	Work trip		Non-work trip	
	Number of households	%	Number of households	%
0	352	100	400	100
2	160	45.54	359	89.75
4	71	20.17	267	66.75
6	42	11.95	200	50.00
8	32	9.09	146	36.50
10	25	7.10	105	26.25
12	19	5.40	82	20.50
14	14	3.98	55	13.75
16	12	3.41	44	11.00

Fig. 3.7   Percentage of Trip Length Longer Than that Shown for
Work Trip and Non-Work Trip
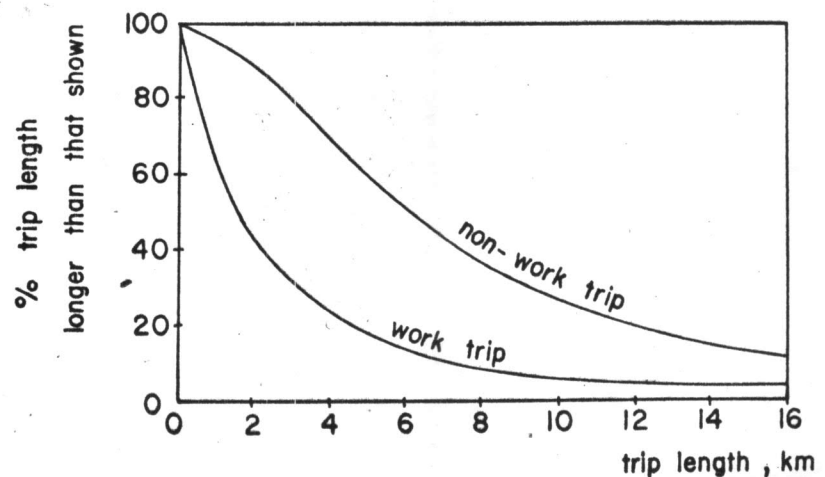
each Tambon were also calculated and shown in Table 3.12. It is
interesting to note that average trip length for non-work trip is
longer than that for work trip due to the fact that work site is
not far from home. For comparison, their distributions were shown
in Table 3.13 and Fig. 3.7. Regardless of purposes of travel, the
average trip length ranges from 4 to 7 kilometers.

3.2.3 Personal mobility index

The multiplication of number of trips being made
during a period of time and their corresponding trip length could
be the expression of capable of movement. Since number of trips
made during a period of time shows the rate or intensity of trips
made by human being and trip length shows human being's scale of
movement capability. Therefore, personal mobility can be expressed
as number of trips-kilometers produced by a household or a Tambon
during a period of time. Table 3.14 shows personal mobility in
each of seven Tambons in the study area. For comparison, personal
mobility in each Tambon is normalized and shown as personal mobility
index in Fig. 3.8. It indicates that the highest personal mobility
index is in Tambon Tak Ok and the lowest one is Tambon Thong Fa.
Since Tambon Tak Ok is the central business district being accessed
conveniently by various modes of transportation of the study area,
whereas Tambon Thong Fa is situated in undeveloped area where can
be accessed only by earth tracks.

Table 3.14 Personal Mobility by Various Modes of Travel in Seven Tambons

Mode of travel	Personal mobility (trip-kilometer/month)						
	Tak Ok	Mae Salit	Samo Khon	Ko Taphao	Tak Tok	Thung Kracho	Thong Fa
Walking	70,735.10	62,294.18	14,885.20	50,581.74	30,644.51	51,733.27	28,150.86
Bicycle	40,106.36	5,010.50	11,501.60	16,302.40	25,495.96	6,272.39	3,517.08
Motorcycle	66,255.00	8,235.44	3,326.40	21,893.06	61,510.28	13,381.63	782.10
Local bus	215,776.76	195,500.60	51,097.20	144,861.00	132,849.61	170,478.30	72,943.86
Long hual bus	153,396.10	12,034.31	35,415.60	115,348.34	97,516.09	15,095.18	3,962.64
Other	80,263.20	17,409.21	10,555.60	18,854.08	11,539.56	16,203.01	9,257.22
All modes	626,532.52	300,484.24	126,781.60	367,840.62	359,556.01	273,163.78	118,613.76

Fig. 3.8 Comparison of Personal Mobility Index in Seven Tambons