Time-of-Day Characteristics of Travel: An Analysis of 1990 NPTS Data

Ryuichi Kitamura and the Department of Transportation Engineering, Kyoto University

Acknowledgments

Mr. Iida and Mr. Seto of the Department of Transportation Engineering, Kyoto University, aided the author in the data analysis of this study. Their assistance is gratefully acknowledged.

List of Tables

Appendix Tables

List of Figures

List of Figures (cont.)

1. Introduction

Despite the fact that what is considered to be the principal transportation problem — namely traffic congestion — represents the concentration of demand along the time dimension, relatively little attention has been directed to the time element in the development of analytical models for travel demand. In particular, the time dimension is noticeably absent in the widely used urban passenger travel demand forecasting procedures known as the "four-step procedures." However, recent emphasis on a wide range of travel demand management (TDM) measures, especially the renewed interest in congestion pricing, has called for more explicit treatment of the time dimension. In fact researchers have focused on departure time choice behavior in attempts to understand and predict the peak spreading phenomenon (e.g., Abu-Eisheh & Mannering, 1987; Chang, Mahmassani & Engquist, 1989). These efforts, however, have tended to focus on commuters' travel choices for their peak-period commute. Extensive analysis of travel demand along the time-of-day dimension and incorporation of the time dimension into the theory and models of travel behavior, remain as future tasks.

The current understanding of temporal aspects of trip making thus remains limited. For example, no effective tool is available for the analysis of induced travel. How would an individual respond when his daily commute consumes an additional 20 minutes due to intensifying traffic congestion? Which activities would he cut back? Would he change destinations for his out-of-home activities to compensate for the increased commute time? And what would he do if he gains 20 minutes a day from reduced traffic congestion resulting from an addition of road capacity? Would he pursue additional out-of-home activities? If so, what activities, when, and where? Addressing these questions is essential for the development of travel behavior theory and for rigorous assessment of transportation policies. Yet the field of travel demand analysis is in its early stages of development with respect to the analysis of travel demand along the time dimension.

This study is an attempt to gain a better understanding of temporal aspects of travel behavior. The focus of the analysis is on the timing of trips made for various purposes. The nature of the study is largely descriptive and explorative. The rich information contained in the 1990 NPTS data is utilized to reveal temporal characteristics of trip making. Explorative analysis is also performed to examine history dependence in out-of-home activity engagement and trip making. The study in addition contains an initial modeling effort to examine the interplay between activity duration and activity timing (therefore trip timing). It is hoped that some general tendencies in temporal aspects of travel behavior can be revealed and directions for future research can be identified through this effort.

This report is organized as follows. In Section 2, the characteristics of trip reporting and the quality of the trip records in the 1990 NPTS data file are discussed. Of particular focus is the accuracy of reported trip starting times. The discussion of this section also covers the re-definition of trip purposes to introduce a "home" trip category into the subsequent analysis. The distribution of trip starting times over the one-day period is examined in Section 3 by trip purpose and by sample sub-group. In Section 4, the conditional distribution of trip purposes, given that a trip is made within a specific time interval, is evaluated and the dependence of activity engagement in its past history is studied. Following this the interplay between activity duration and activity timing is explored in Section 5. Section 6 is a brief summary.

2. Quality of Trip Reporting

The completeness of trip reporting and the accuracy of reported trip attributes are the basis that facilitates credible inference of the characteristics of travel behavior. The quality of trip reporting in the 1990 NPTS data is examined in this section prior to the analysis of the data set in this study.

Fraction of Travelers

Of the total of 48,385 individuals from 22,317 households, 10,239 individuals (21.2%) responded that they did not make any trip on the survey day (see Table 2.1; statistics in this report are unweighted). This figure, which presumably includes those who refused to provide trip information, may be in part due to under-reporting of trips in the survey.

The fraction of individuals who do not report trips at all on a given day is an important indicator of the quality of travel survey. Statistics reported in Purvis (1994) indicate that the fraction of individuals reporting at least one trip on a survey day ranges from 78% in a 1981 Sydney survey to 87% in a 1977 Adelaide survey. The person trip surveys in the San Francisco Bay Area in 1981 and 1990 both contained approximately 82% of respondents reporting at least one trip. The 1990 NPTS data set thus contains a slightly more fraction of respondents reporting no trips at all than do the Adelaide survey data, but not notably more than do the two San Francisco surveys.

The validity of the indication from the NPTS data set that slightly more than one individual out of five do not make any trip at all on a survey day is difficult to assess. The difficulty is two-fold. Firstly, trip records do not facilitate the estimation of the fraction of people who make trips on a day (or, "travelers") due to under-reporting of trips that are prevalent in person trip surveys. Secondly, our ability to make inferences about travel characteristics of the population may be significantly impaired because of possible selectivity bias contained in the trip records. Namely, those who reported their trips may be systematically different from those who made trips but did not report them, and from those who did not respond to the survey at all.

Table 2.1: DISTRIBUTION OF RESPONDENTS BY THE NUMBER OF TRIPS REPORTED

No. of Trips	No. of Persons	%
0	10,239	21.2
1	689	1.4
2	14,698	30.4
3	4,157	8.6
4	7,415	15.3
5	3,342	6.9
6	3,016	6.2
7	1,620	3.4
8	1,162	2.4
9	768	1.6
10	449	0.9
11	262	0.5
12	169	0.4
13	163	0.3
14	83	0.2
15	153	0.3
≥ Total	48,385	100.0

It is known that the likelihood that an individual chooses to participate in a survey is correlated with certain attributes of the individual, some of which are such commonly used demographic and socio-economic variables as income and education. Past analyses of attrition in panel surveys — where factors contributing to survey participation can be conveniently examined by observing whether a person will continue to participate in a series of repeated surveys — have indicated that education and age are important contributing factors (Kitamura & Bovy, 1987). This is likely to be the case for trip reporting as well. Because of this, the validity of findings — even those that are well accepted — is subject to the quality of trip reporting in the data sets on which they are based. For example, it is commonly

believed that the trip rate peaks when a person is in the 35-to-55 age bracket. Results reported in Purvis (1994), however, indicate that the fraction of individuals who do not report trips at all increases with age. Part of this is due to the genuine relationship between age and trip making, while part of it is due to possible correlations between age and trip reporting. The above finding that the trip rate peaks with the middle age then may be exaggerated due to trip under-reporting. Although it is outside the scope of this present study, it is extremely important that the two groups of individuals — those who reported trips and who did not — be thoroughly examined and the nature of possible biases be identified.

Mean Daily Trip Rates

The total number of trips contained in the data set is 149,546. The overall mean trip rate is 3.09 (= 149,546/48,385), while the trip rate for the 38,146 travelers in the data for whom at least one trip is recorded, is 3.92 (= 149,546/38,146). (Trip rates are computed without making any adjustment to the number of trips contained in the data file, and include trips with missing information. All individuals in the data file are contained in the tabulation.) These trip rates are not necessarily lower than those found in other travel survey data sets (see Purvis, 1994). Yet, they are substantially lower than a mean trip rate of 5.18 inferred from a California time use data set (Kitamura et al., 1992).

Individuals Who Reported Only One Trip

There are 689 individuals (1.42% of the total) for whom only one trip is recorded. These individuals contain almost equal numbers of those who reported one home-to-other trip (327 individuals, or 47.5%) and those who reported one other-to-home trip (324, 47.0%) on the survey day (see Table 2.2). The data thus suggest that 1.4% of individuals (or 1.81% of travelers) did not have a complete home-to-home journey pattern during the survey day.

Table 2.2: TYPES OF TRIPS RECORDED FOR THOSE REPORTING ONLY ONE TRIP

Type of Trip	No. of Persons	%
Home to Home	0	0.0
Home to Other	327	47.5
Other to Home	324	47.0
Other to Other	34	4.9
Unknown	4	0.6
Total	689	100.0

Consistency of Recorded Trip Attributes

The consistency of recorded trip starting and ending times and origin and destination codes is checked for those 37,457 individuals for whom two or more trips are recorded. For trip times, two types of inconsistency are examined. The first possibility involves the case where the recorded starting time of the n-t trip is earlier than that of the (n-1)-th trip. The second case represents the situation where the starting time of the n-th trip is earlier than the starting time of the (n-1)-th trip plus the duration of the (n-1)-th trip.

The total number of trips recorded for individuals with two or more trips is 148,857. Of these, 2,910 trips (1.95%) involve inconsistency of the first type, and another 5,425 trips (3.64%) contain that of the

second type (Table 2.3). Altogether, inconsistent trip starting and ending times are recorded for over 8,300 trips. In addition, there are 6,001 trips for which trip starting times are missing. In sum, no indication of inconsistency can be found for slightly over 90% of the trips recorded for those respondents who reported two or more trips, while nearly 10% of the trips contain either inconsistent or missing starting time information.

Table 2.3: CONSISTENCY IN RECORDED TRIP STARTING TIME (INDIVIDUALS WITH TWO OR MORE TRIPS)[1]

Type of Inconsistency	No. of Trips	%
Trips with Consistent Starting Time (Including First Trip of Day)	134,521	90.4
Starting Time Earlier Than That of Previous Trip	2,910	2.0
Starting Time Earlier Than That of Previous Trip Plus Its Duration	5,425	3.6
Trip Starting Time "Not Ascertained"	4,093	2.8
Respondent "Refused" to Report Trip Starting Time	1,908	1.3
Total	148,857	100.0

The continuity of the origin and destination codes across successive trips is also examined in a similar manner. The results indicate that there are only less than ten trips for which discontinuity can be found (Table 2.4). The origin/destination codes are presumably logically generated with computer post-processing, and appear to possess high quality.

Distribution of Reported Minutes of Trip Starting Times

To examine the accuracy of reported trip starting times, they are classified into four quarters of the hour based on the reported minutes: 0 to 14 min., 15 to 29 min., 30 to 44 min., and 45 to 59 min. The frequency of reported starting minutes is tabulated by trip purpose and summarized in Table 2.5. As is clear in the table, the frequency of trips in the first quarter (0 - 14 min.) and that of trips in the third quarter (30 - 44 min.) are much greater than the frequencies in the second (15 - 29 min.) and fourth (45 - 59 min.) quarters.

Table 2.4: CONSISTENCY OF RECORDED TRIP ORIGIN/DESTINATION INFORMATION

Type of Inconsistency	No. of Trips	%
Consistent Origin/ Destination Information	149,465	99.95
Destination of Previous Trip Is "Home," and Origin of Trip is "Not Ascertained."	2	*
Destination of Previous Trip Is "Other," and Origin of Trip is "Refused."	6	*
Origin of Trip "Not Ascertained"	43	0.03
Origin of Trip "Refused"	6	*
Destination of Trip "Not Ascertained"	14	0.01
Destination of Trip "Refused"	10	0.01
Total	149,546	100.00

*Less than 0.005%

[1]When inconsistent trip time information is found between two successive trips, only the second trip is tallied to contain inconsistent information, while the first trip is assumed to have correct trip time information. No inconsistency is flagged if either of the two trips has missing trip time information.

Further inspections of the data indicated that more than 35% of trips have reported starting times at an exact hour (0 min.) and nearly 30% have those exactly at a half past an hour (30 min.). Altogether, 81.9% of trips are reported to have started at exact quarters (Table 2.6). In other words, the respondents may have round their trip starting times to the nearest quarters for over 80% of trips. Furthermore, the fact that 64.0% of trip reported starting times are either at an exact hour or 30 minutes past an hour suggests that this rounding may have been done to the nearest half hours. The results suggest that the quality of trip reporting in the data may be poor. Obviously trip starting times and therefore elapsed times between trips cannot be established with high precision based on the trip starting times recorded in the data file.

Returning to Table 2.5, it is clear that the tendency of trip starting time rounding varies across trip purposes. Starting times appear to be more accurately reported for trip purpose categories of Work and School/Church, while rounding is more pronounced for Shopping and Visit Friends or Relatives. Apparently trip starting times are easier to recall and report for such mandatory and repetitive trips as commuting which tend to be long and have regular starting times. On the other hand, starting times appear to be only approximately reported for discretionary and irregular trips made for such purposes as shopping and social visits for which much larger degrees of freedom are associated in terms of timing.

Table 2.5: DISTRIBUTION OF TRIPS BY REPORTED STARTING QUARTER BY PURPOSE

Trip Purpose	00 - 14		15 - 29		30 - 44		45 - 59		Total
	N	%	N	%	N	%	N	%	
To and from Work	5,627	36.0	2,078	13.3	5,241	33.6	2,668	17.1	15,614
Work-related Business	609	38.7	229	14.6	516	32.8	218	13.9	1,572
Shopping	8,420	48.4	1,818	10.5	5,539	31.9	1,615	9.3	17,392
Family/Personal Business	8,508	39.2	3,092	14.3	6,776	31.2	3,317	15.3	21,693
School/Church	3,079	32.7	1,563	16.6	2,896	30.8	1,867	19.9	9,405
Medical/Dental	393	38.6	147	14.4	323	31.7	155	15.2	1,018
Vacation	96	61.5	14	9.0	37	23.7	9	5.8	156
Visit Friends/Relatives	4,351	50.0	848	9.7	2,741	31.5	771	8.9	8,711
Pleasure Driving	163	49.9	31	9.5	107	32.7	26	8.0	327
Other Social/Recreational	5,839	43.4	1,543	11.5	4,427	32.9	1,654	12.3	13,463
Other	268	38.0	103	14.6	236	33.4	99	14.0	706
To Home	21,642	40.5	7,704	14.4	17,107	32.0	7,018	13.1	53,471
Total	37,353	41.5	11,466	12.7	28,839	32.0	12,399	13.8	90,057

Re-definition of "Home" Trips

Table 2.6: DISTRIBUTION OF TRIPS BY RECORDED STARTING MINUTE

Minutes	No. of Trips	%	% (Cumul.)
00	51,999	36.2	36.2
30	39,847	27.8	64.0
45	13,223	9.2	73.2
15	12,433	8.7	81.9
Other	26,043	18.1	100.0
Total	143,545	100.0	

The NPTS trip purpose coding scheme is based on the "reason for which the trip was made." Therefore the conventional "home" trip category is absent in the original data file. Consequently it is not possible to distinguish on the sole basis of the trip purpose categories whether a trip was made to a destination to engage in an activity, or to leave a destination for home after completing activity engagement. This presents a problem for the analysis of trip making by time of day since trip starting times must be tallied separately for trips to activity locations and those from activity locations. Furthermore, unambiguously defining "home" trips is essential for analyzing trip linkages or trip chaining. More importantly, trip rates computed using the NPTS trip purpose codes are not compatible with those obtained using the conventional trip purpose codes. For those reasons, it was attempted to identify home trips based on the information available in the NPTS trip records.

Our inspection of the trip records has indicated that the coding of trip purposes needs to be carefully interpreted when trips are linked to visit more than one destination after leaving home. For example, consider a trip purpose sequence, work - shopping - home. Based on reasons for which these trips were made, they may be coded as work - shopping - shopping or work - shopping - work. This is illustrated with the following sample of trip purpose sequences from the 1990 NPTS data file:

a. [Home] → *Work* → [Work] → *Pers. Bus.* → *Soc./Rec.* → *Work* → [Home]

b. [Work] → *Work* → [Home] → *Soc./Rec.* → *Soc./Rec.* → [Home] → *Work* → [Work]

c. [Home] → *Soc./Rec.* → *Soc./Rec.* → *Soc./Rec.* → *Work* → [Work] → *Soc./Rec.* → *Work* → [Home] → *Soc./Rec.* → *Soc./Rec.* → [Home]

d. [?] → *Work* → [Work] → *Pers. Bus.* → *Pers. Bus.* → *Pers. Bus.* → *Shopping* → *Soc./Rec.* → *Pers. Bus.* → [Home]

e. [?] → *Work* → [Work] → *Pers. Bus.* → [Home] → *Pers. Bus.* → *Work* → [Home]

f. [Home] → *Work* → [Work] → *Shopping* → *Work* → [Home]

g. [Home] → *Work* → [Work] → *Pers. Bus.* → *Pers. Bus.* → *Shopping* → *Work* → [Home]

h. [Home] → *Pers. Bus.* → *Pers. Bus.* → [Home] → *Shopping* → *Shopping* → [Home] → *Work* → [Work] → *Work* → [Home]

i. [Home] → *Pers. Bus.* → *Pers. Bus.* → [Home] → *Medical/Dental* → *Medical/Dental* → [Home] → *Work* → *Work* → [Work] → *Work* → *Work* → [Home]

j. [Home] → *Soc./Rec.* → *Soc./Rec.* → [Home] → *Work* (Walk) → *Work* (Bus) → [Work] → *Work* → (Auto) → [Home]

where italicized words indicate the "reason for which the trip was made" as coded in the data file, and a word in brackets indicates the base of the trip as identified from trip origin/destination categories. As can be seen from these sample of 10 daily trip purpose sequences, the last trip back to the home base is coded to have the purpose identical to the purpose of the first trip that originated from home (see sequences a, b, f, g, h, i and j). Trip purpose coding, however, appears to deviate from this in some cases where there is an intermediate stop at the work base. For example, in sequence c, the first return trip to home is coded to have

a work purpose, while the trips which originated from home have a social/recreation purpose. In sequence d, the purpose of the last home trip, personal business, is identical to the purpose of the trip originated from the work base, while the coding of the last home trip in sequence e appears to be based on the purpose of the first trip.

Based on the inspection of the trip purpose coding in the data file, it is concluded in the study that trip purpose codes in the NPTS data file can be converted to ones that are compatible with the conventional trip purpose categories used in transportation planning by changing the purpose category to "home" for those trips whose destinations are coded as the home base. The analyses presented in the rest of this report are based on this conversion of trip purpose categories.[2]

[2]Additional problems of the NPTS trip purpose classification found during this study include: (1) grouping together of "school" and "church," and (2) absence of the "serve-passenger" category.

3. Distribution of Trip Starting Times

The temporal distribution of trip starting times and trip rates by purpose are examined in this section for sample sub-groups defined in terms of age, gender, employment and role. Temporal distributions of trip starting times are shown in Appendix Figures 3.1 through 3.4 for sub-groups defined in terms of household size, life-cycle stage, driver's licensing holding, and MSA size.

Distribution by Age

The distribution of trip starting times is tabulated by trip purpose for five age groups. Appendix Table 3.1 gives the number of travelers in each age category and the total number of trips and the trip rate by purpose, for individuals at least 16 years old. Consistent with previous findings in the literature, the person trip rate increases with age and peaks in the 25-to-49-years-old range, then declines. The work trip rate shows a peak in the 35-to-49-years-old bracket. This age group also has the largest number of trip chains. The work trip rate is extremely low for the over-65-years-old range which represents the retirement age. Shopping and other family or personal business trips exhibit similar tendencies. The trip rates for visiting friends or relatives and other social or recreational trips, on the other hand, tend to decline with age, although some irregularities can be found in the table. In particular, the trip rates for these purposes increase for the oldest age group.

Temporal distributions of trip starting times are shown by trip purpose and by age group in Figures 3.1.a through 3.1.j. The figures are prepared using 30-minute intervals and present, for each trip purpose, the mean trip rate within each time interval for each sub-group. Namely each point on the line graph represents the total number of trips made by the sub-group members for the specific trip purpose during the 30-minutes interval, divided by the number of respondents in the sub-group. The figures thus represent differences in trip rates across sub-groups as well as the temporal distribution of trips for each sub-group.

Work trip starting times show similar peaks for all age groups (Fig. 3.1.a). Quite notable is the result that the youngest age group shows high frequencies during the afternoon off-peak period. Reflecting its low rate of work trip generation, the frequency curve for the oldest age group is consistently low. Work-related business trips show rather irregular patterns across the age groups (Fig. 3.1.b). These trips tend to concentrate during the 8:00 a.m. to 5:00 p.m. period, although their generation continues into evening hours.

As noted earlier, shopping trips exhibit craggy patterns with more trips recorded in the first half of each hour than in the second half (Fig. 3.1.c). An inspection of the figure indicates that the oldest age group tends to pursue shopping in earlier parts of the day, with very low trip rates after 4:30 p.m. or so. Morning shopping trip generation declines while evening trip generation increases as one moves toward younger age groups. In particular, the youngest, 16-to-24-years-old age group, which happens to have the lowest shopping trip generation rate among the age groups, has a peak for shopping trips in the 3:00-to-6:00-p.m. period, and maintains high rates through the evening. Similar tendencies can be found for trips for other family or personal business (Fig. 3.1.d).

The temporal distribution of school trips is unique in that the youngest age group, which contains full-time students, exhibits a pattern that is entirely different from those of the other age groups (Fig. 3.1.e). The youngest group has a sharp peak around 7:30 a.m., representing commute trips to school by full-time students. The other groups have peaks around 9:00 a.m. and 6:30 p.m., but school trip generation by these older age groups tends to be spread through the business hours of the day.

Trips for medical and dental purposes tend to be confined within the typical business hours of 8:00 a.m. to 5:00 p.m., although trips are recorded in early morning and evening hours as well (Fig. 3.1.f). The distribution patterns are rather irregular, presumably due to the small number of trips for these purpose in the data file.

Trips for social visits are spread from mid-morning to early morning hours (Fig. 3.1.g). Like in the case for shopping, the youngest age group exhibits a clear tendency with trip rates that increase toward early evening hours. Its trip generation for social visits peaks around 6:30 p.m., then gradually declines. Yet, this group generates substantially more trips of this type in late evening and early morning hours than do any other groups. The figure displays a clear pattern that trip generation for social visits in evening hours declines with age.

Like social visits, pleasure driving is an activity that is pursued from mid-morning to early morning (Fig. 3.1.h). Due to the small number of trips for this purpose, the figure does not offer consistent patterns. Yet one can notice that the youngest group has high trip rates during the evening hours.

Trips made for other social or recreational purposes follow patterns similar to those for social visits (Fig. 3.1.i). Again, engagement in these activities gradually increases as the day progresses and peaks around 7:00 p.m. Unlike social visits, however, small peaks can be found around 12:00 noon and dips can be found around 3:00 p.m. These tendencies can be seen for almost all age groups. The youngest age group again presents high trip generation rates in evening hours, but its pattern is not so distinct from those of the other groups as in the case for social visits.

The temporal distribution of trips to return home can be found in Figure 3.1.j. The figure shows clear peaks during the evening peak-period, around 5:00 p.m., and another set of peaks around 12:00 noon. Home trips are least frequent during the early morning hours of 4:00 a.m. to 6:00 a.m., then gradually build up toward the noon peaks. After some sags around 1:00 to 2:00 p.m., home trip generation continues to increase toward the afternoon peaks, then gradually subsides. As before, the older age groups tend to have lower home trip generation rates in evening to early morning hours; older individuals evidently retire to home earlier.

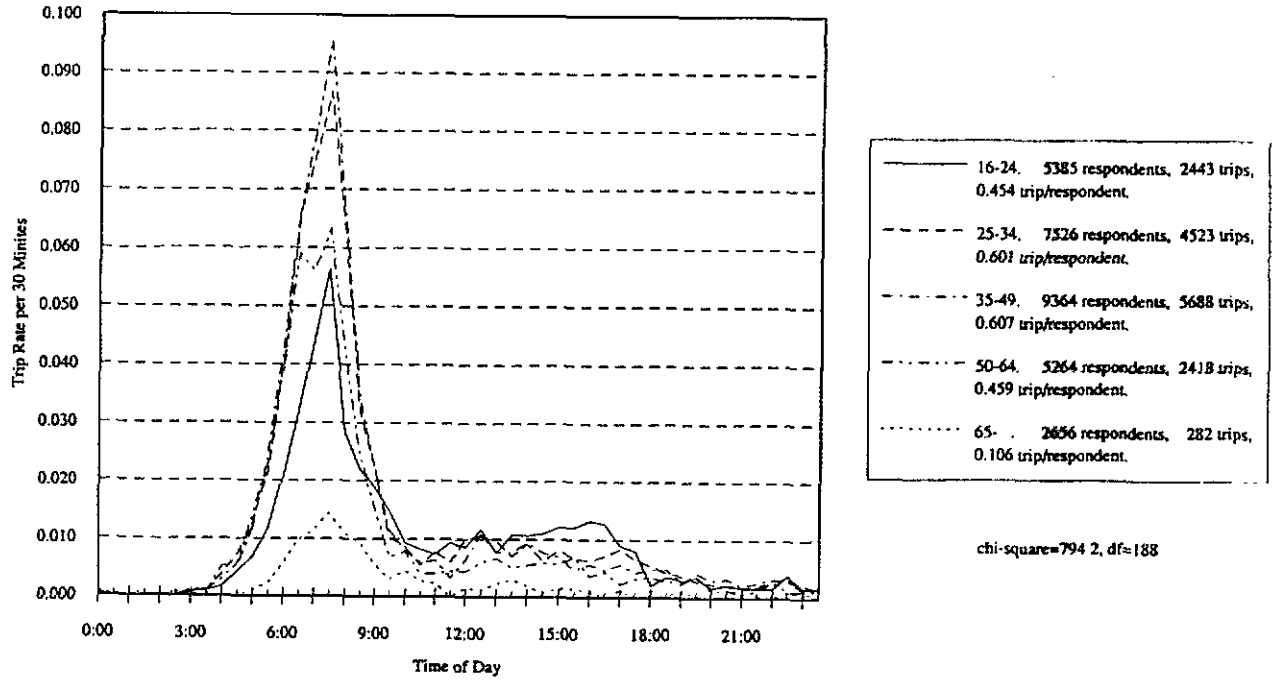


Figure 3.1.a Distribution of Trip Starting Times by Age: To work

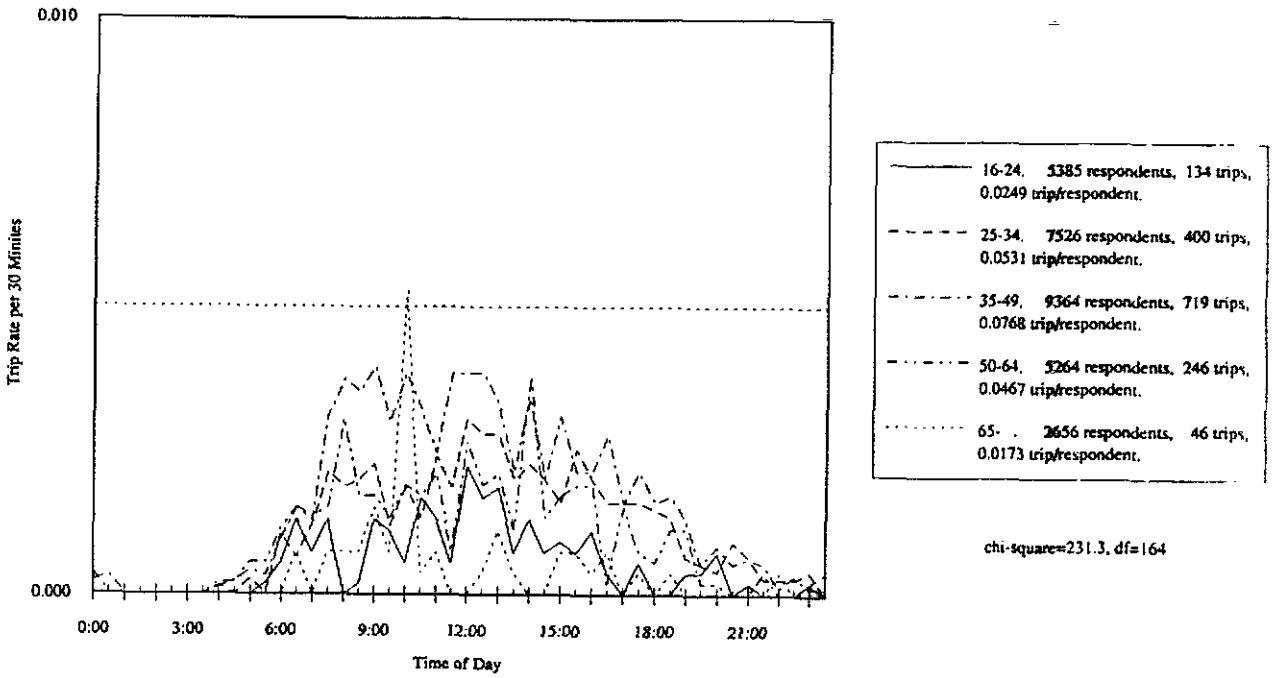


Figure 3.1.b Distribution of Trip Starting Times by Age: Work-related business

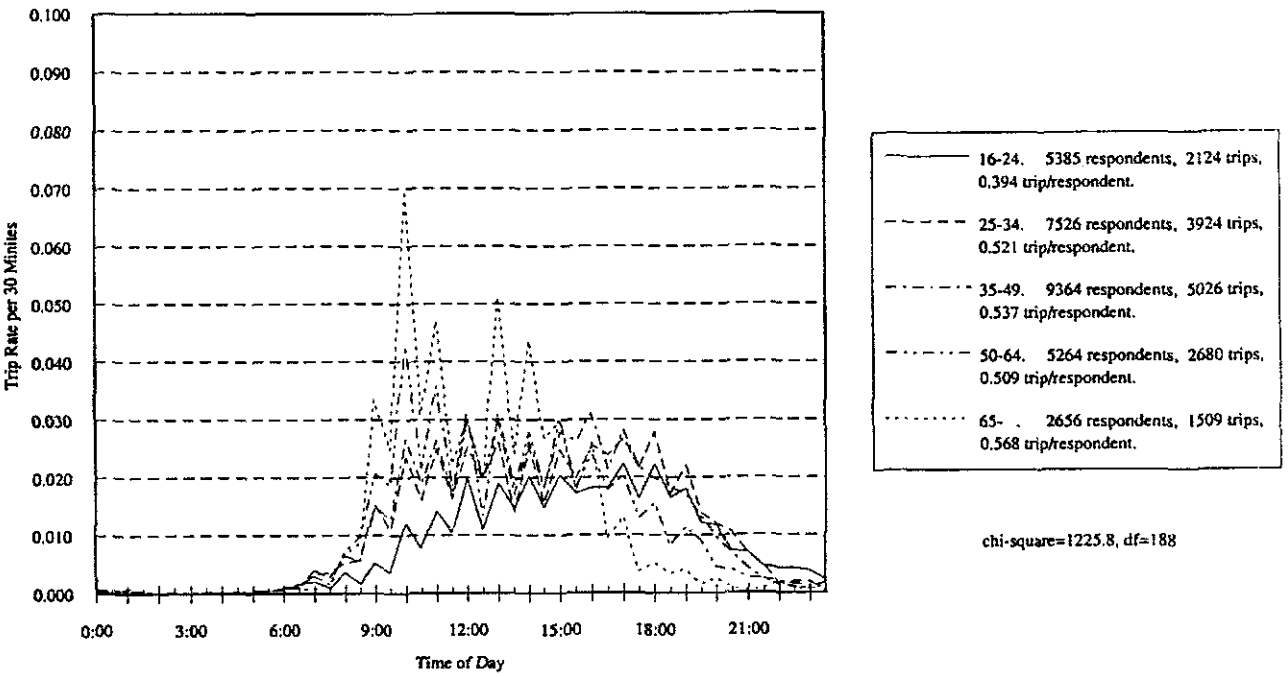


Figure 3.1.c Distribution of Trip Starting Times by Age: Shopping

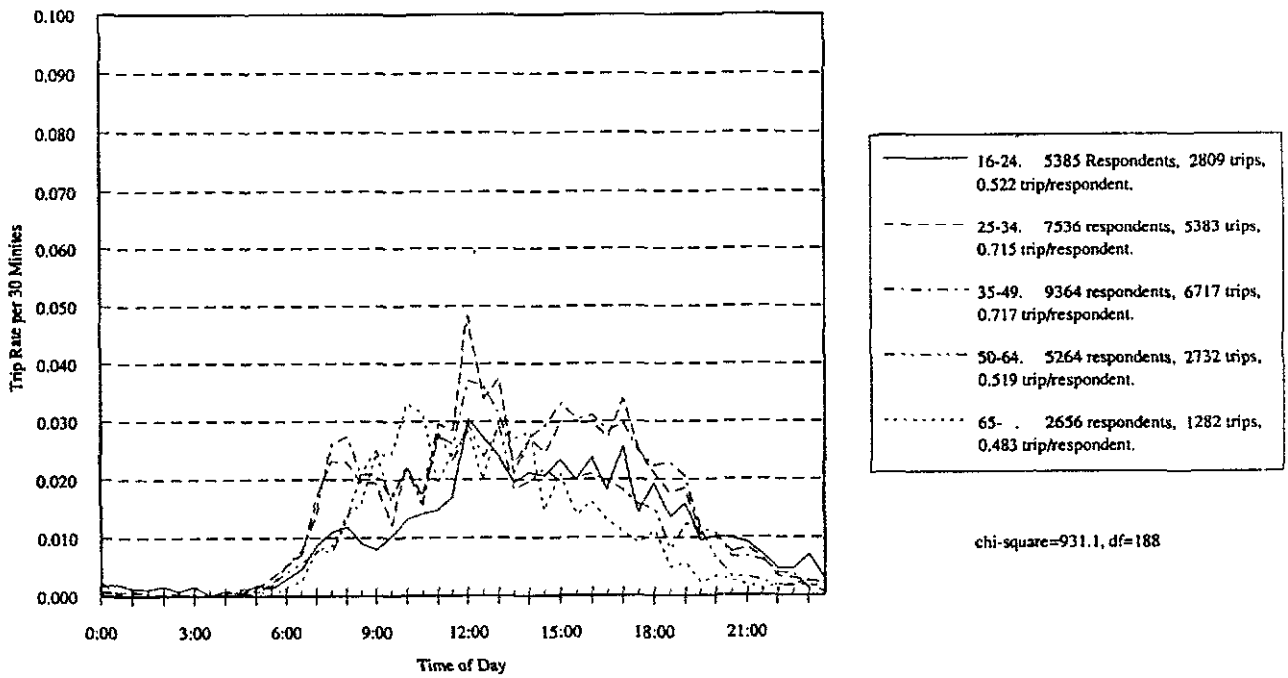


Figure 3.1.d Distribution of Trip Starting Times by Age: Other family or personal business

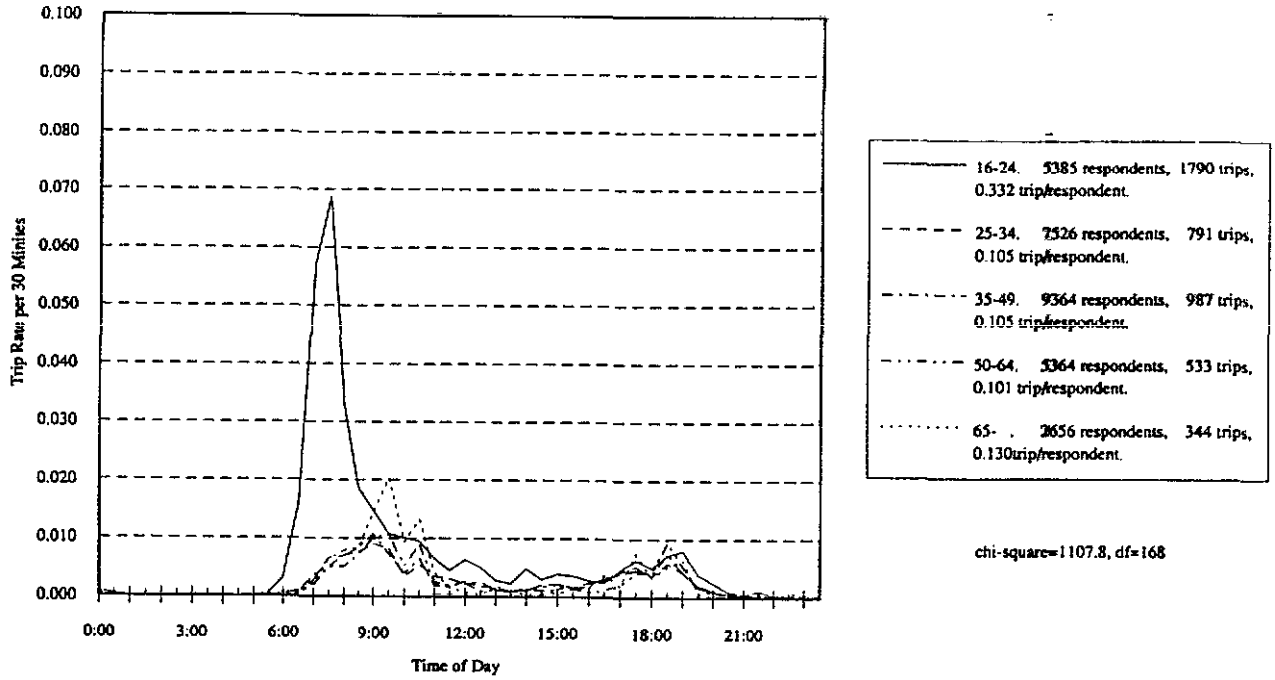


Figure 3.1.e Distribution of Trip Starting Times by Age: School/church

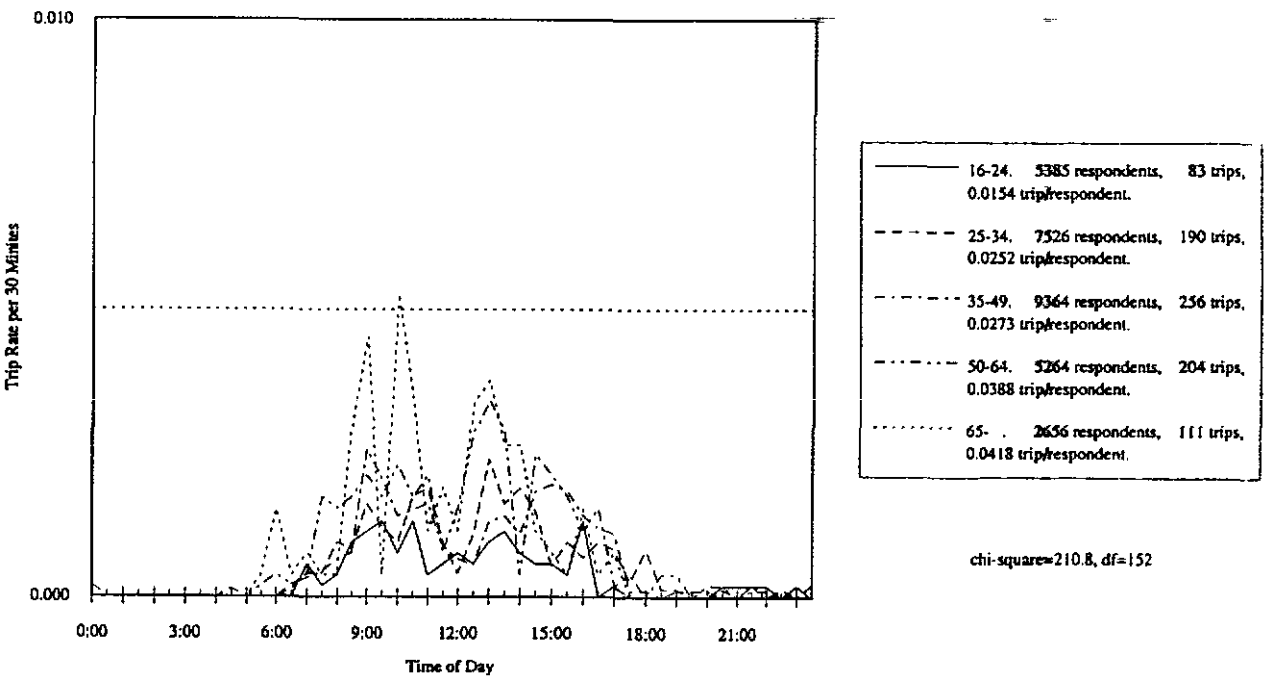


Figure 3.1.f Distribution of Trip Starting Times by Age: Doctor/dentist

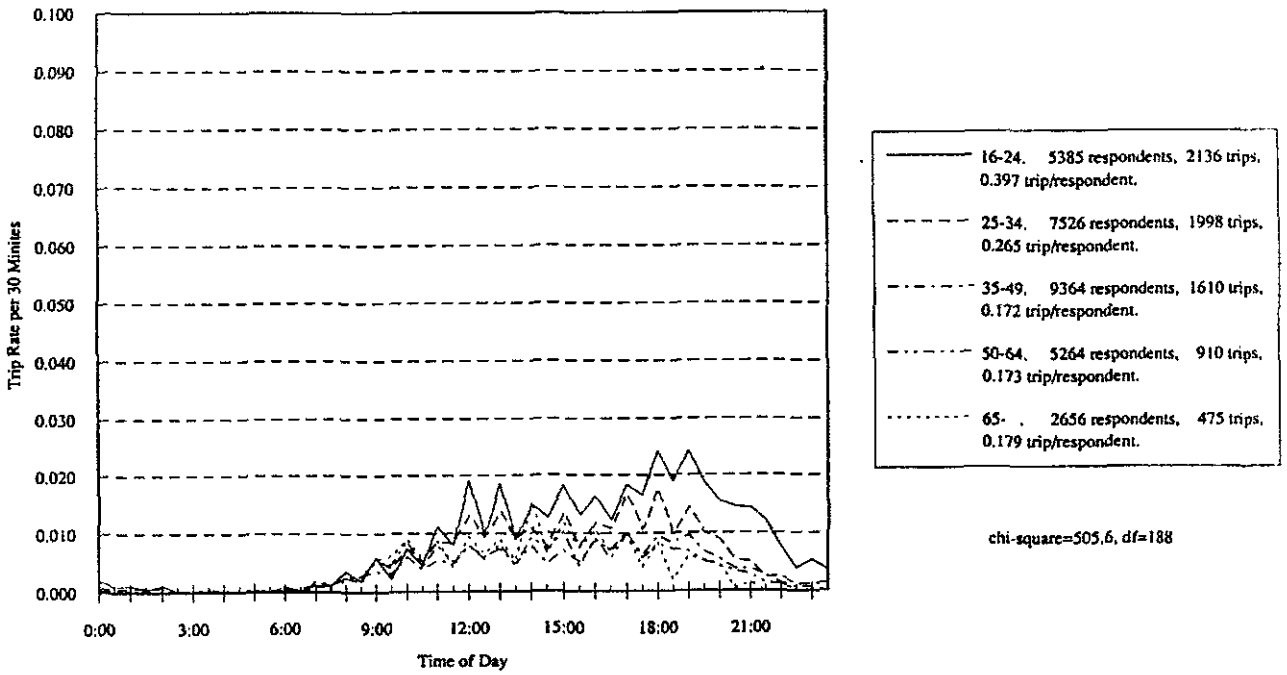


Figure 3.1.g Distribution of Trip Starting Times by Age: Visit friends or relatives

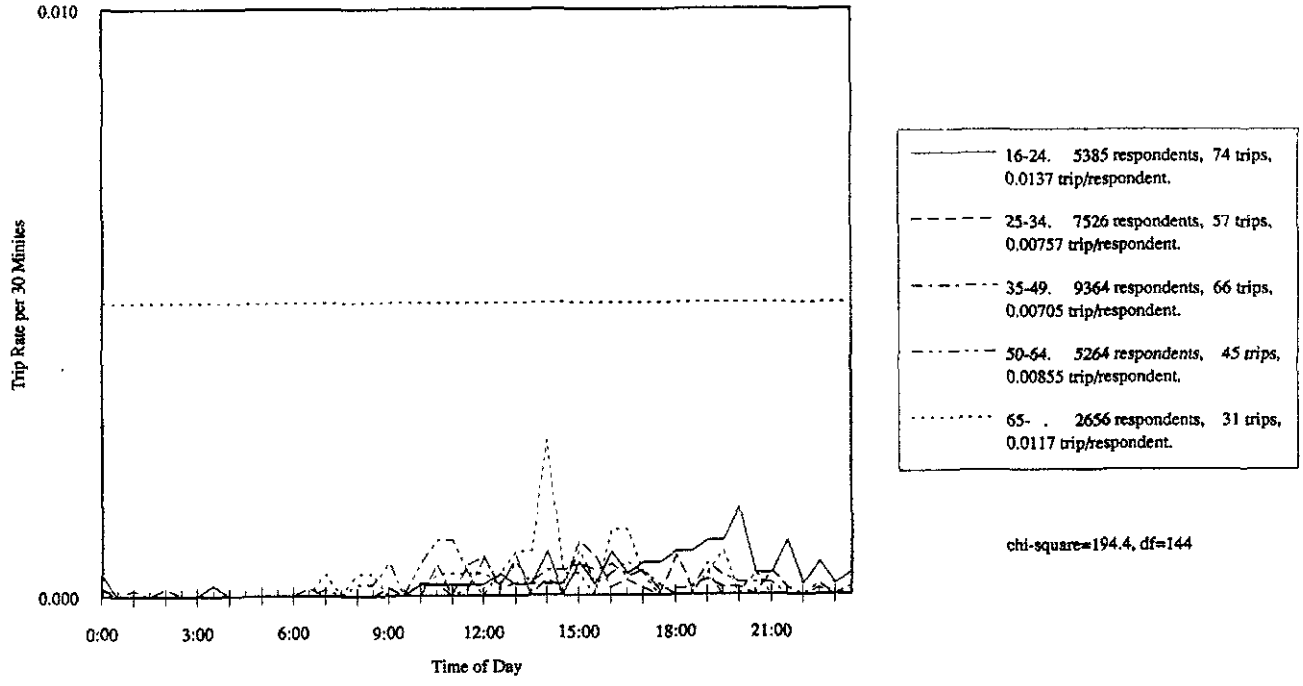


Figure 3.1.h Distribution of Trip Starting Times by Age: Pleasure driving

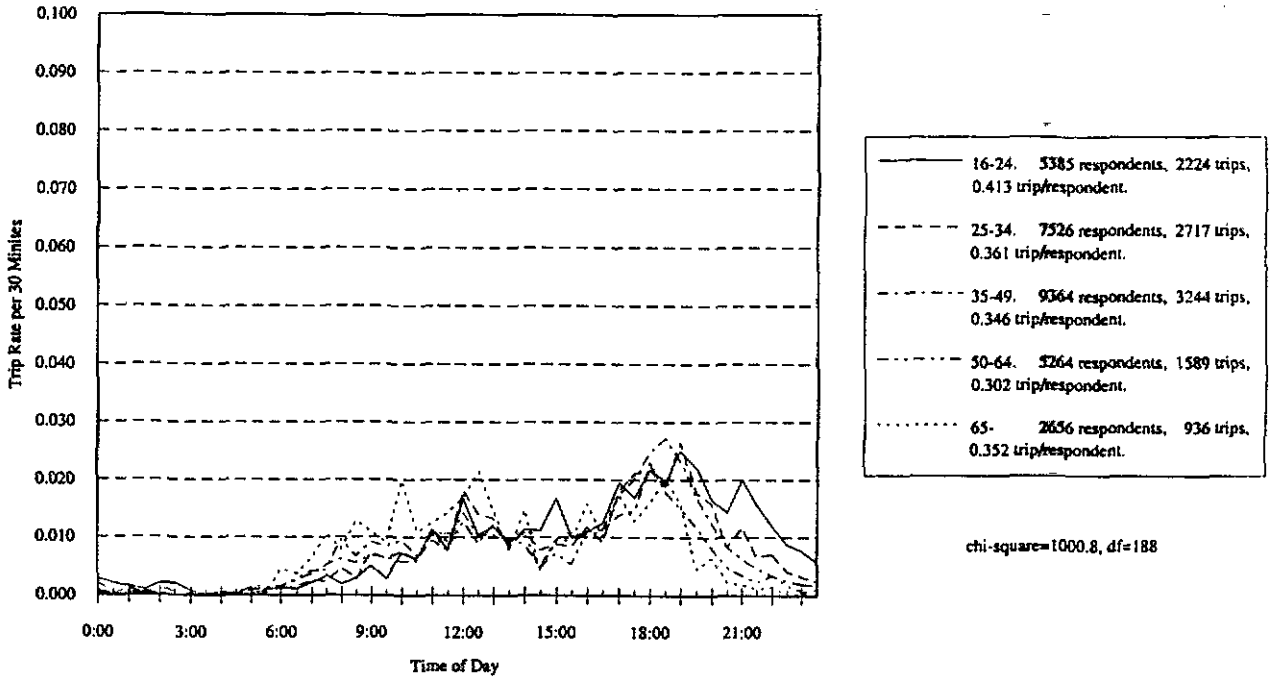


Figure 3.1.i Distribution of Trip Starting Times by Age: Other social or recreational

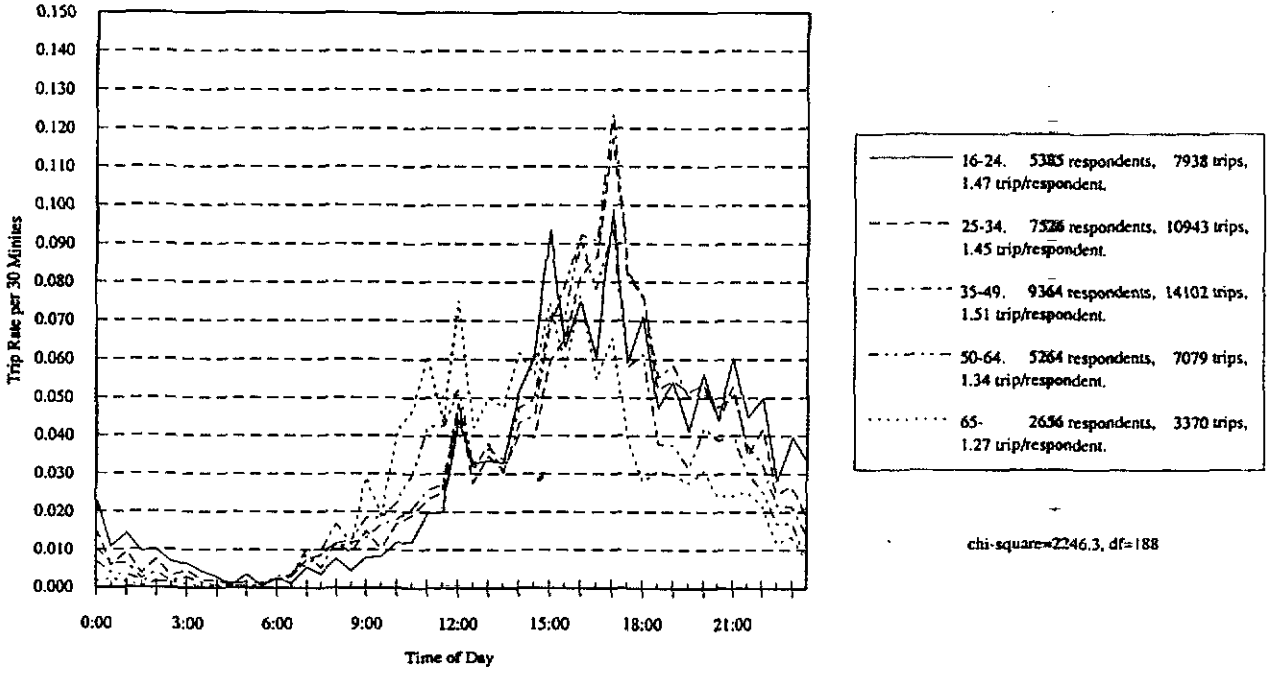


Figure 3.1.j Distribution of Trip Starting Times by Age: To home

Distribution by Sex

The total number of reported trips is summarized by purpose in Appendix Table 3.2 for 38,135 individuals who reported at least one trip (the total number of persons does not agree with 38,146 due to missing sex data). Individuals of all ages are included in this tabulation. Consistent with previous findings on gender differences in travel behavior, the table indicates that men tend to make more trips for work and work-related business purposes than do women, while women tend to make more trips for shopping and family and personal business purposes. In this data set, trip rates for social visits and other social or recreational purposes differ only slightly between men and women.

Temporal distributions of trips are shown by purpose and by gender in Figures 3.2.a through 3.2.j. The temporal distribution of work trips is very similar between the two sexes, except for the fact that men's morning peak starts earlier by 30 minutes to one hour than women's peak (Fig. 3.2.a). The peak ends about the same time for both men and women. Thus men have a morning peak for commute trips that are longer than that of women.

As noted earlier, women have a mean trip rate for work-related business which is much smaller than that of men. In addition, women exhibit a peak during the noon hour, while men have peaks in the mid-morning and early afternoon (Fig. 3.2.b). This, however, could be an artifact of the relatively small sample size available for trips made for this purpose.

Women's shopping trip rates exceed those of men in almost all time intervals of the day (Fig. 3.2.c). Overall patterns of temporal distribution, however, are similar between the two genders. It is also notable that trip rates are practically identical between men and women for the early morning (till 9:00 a.m.) and the evening (after 7:00 p.m.). Likewise, women have higher trip rates for other family or personal business throughout the day (Fig. 3.2.d). Both men and women have peaks at 12:00 noon and at around 3:00 p.m.

School trips exhibit practically the same temporal distributions for men and women (Fig. 3.2.e). Sharp peaks can be observed at around 7:30 a.m. Women have slightly higher school trip rates outside the peak period.

This tabulation of the 1990 NPTS data indicates that women have a higher mean trip rate for medical and dental purposes. This is the case in almost all periods of the day (Fig. 3.2.f). This gender difference, however, could be due to trips taken by women to take their children to the doctor's and dentist's. Although these trips have traditionally classified as "serve-passenger" trips, the data coding in the NPTS data file does not adopt this trip purpose category. This represents serious limitations of the NPTS data set as it does not lend itself to a more fundamental analysis of travel behavior through the examination of individuals' activity engagement and intra-personal interactions within the household.

Relatively little differences can be observed between the two gender for trips for social visits (Fig. 3.2.g), pleasure driving (Fig. 3.2.h), other social and recreational (Fig. 3.2.i) and trips for home (Fig. 3.2.j). The differences are thus most prominent for trips made for household-defined and role-oriented activities such as shopping and personal business. It is conceivable that significant difference could have been observed between men and women for serve-passenger trips had they been separated out as a trip purpose category in the NPTS data coding. The similarity in the temporal distribution of home trips implies a high degree of regularity in out-of-home activity completion between men and women.

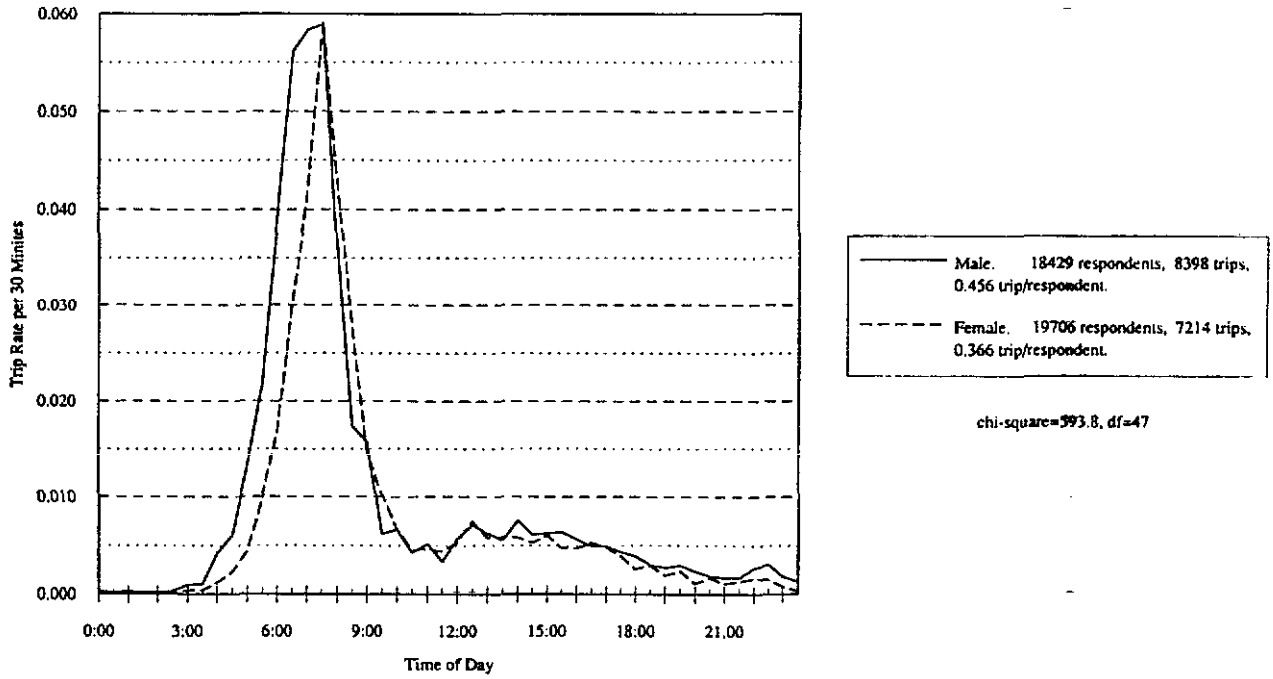


Figure 3.2.a Distribution of Trip Starting Times by Sex: To work

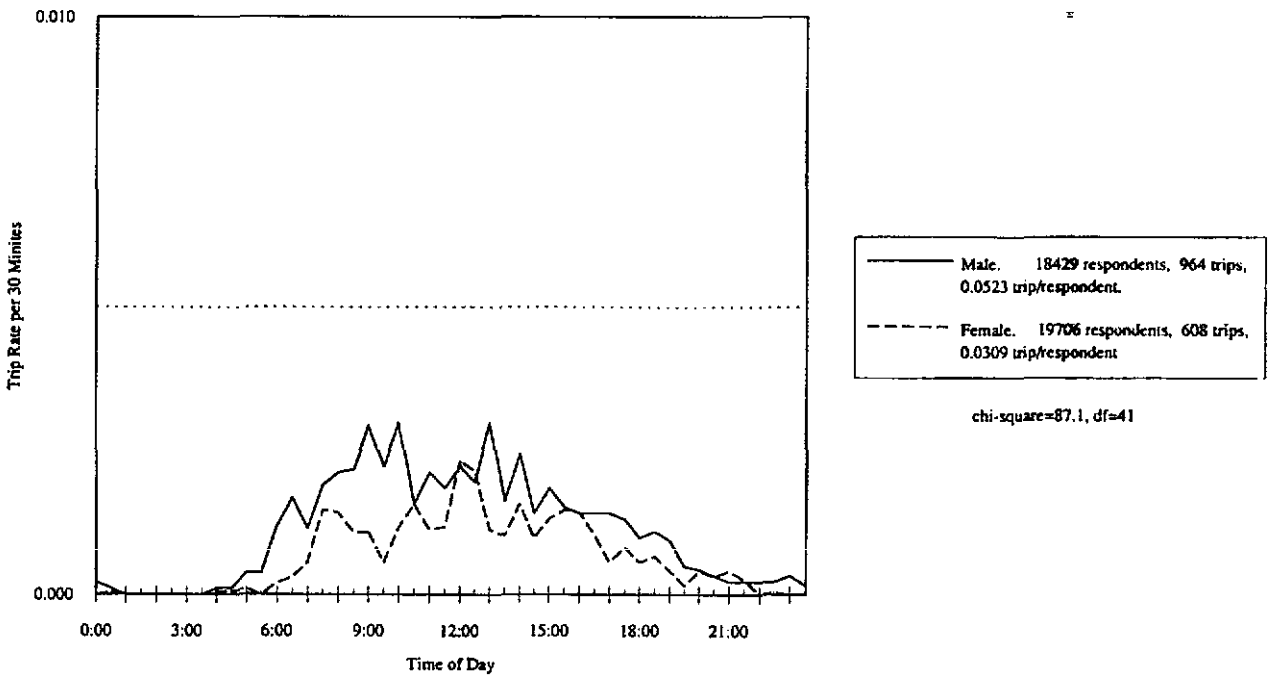


Figure 3.2.b Distribution of Trip Starting Times by Sex: Work-related business

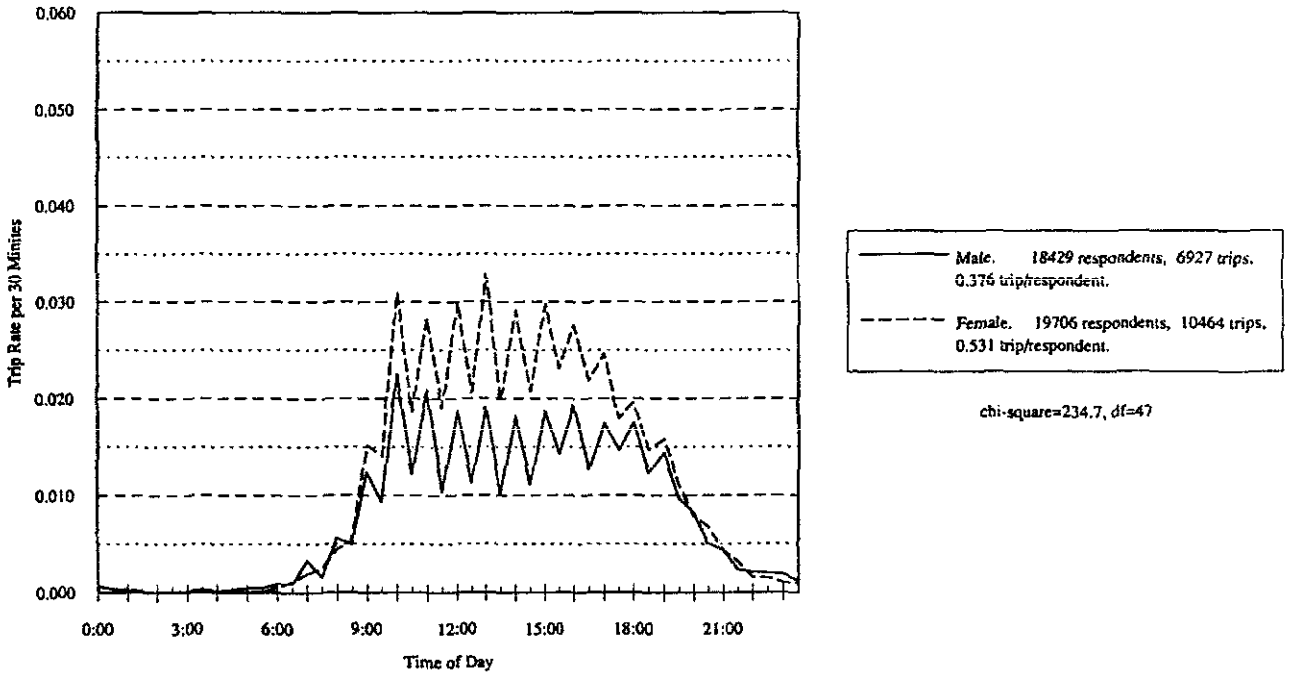


Figure 3.2.c Distribution of Trip Starting Times by Sex:Shopping

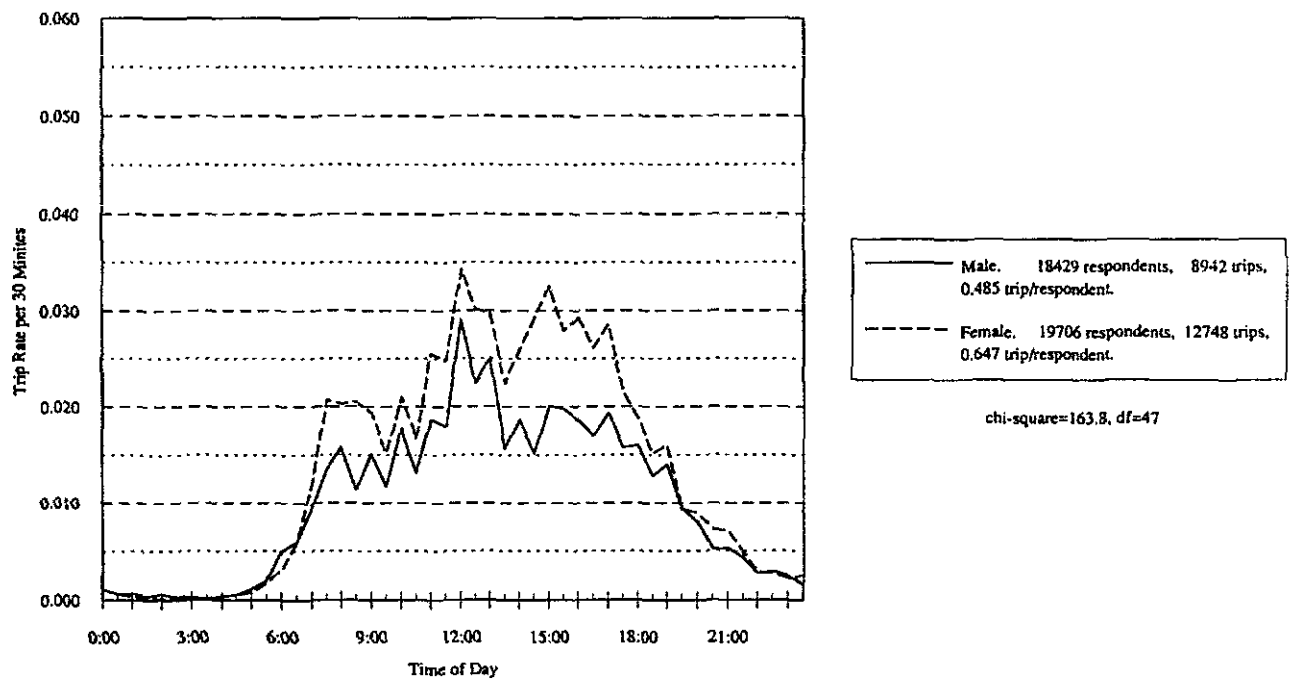


Figure 3.2.d Distribution of Trip Starting Times by Sex: Other family or personal business

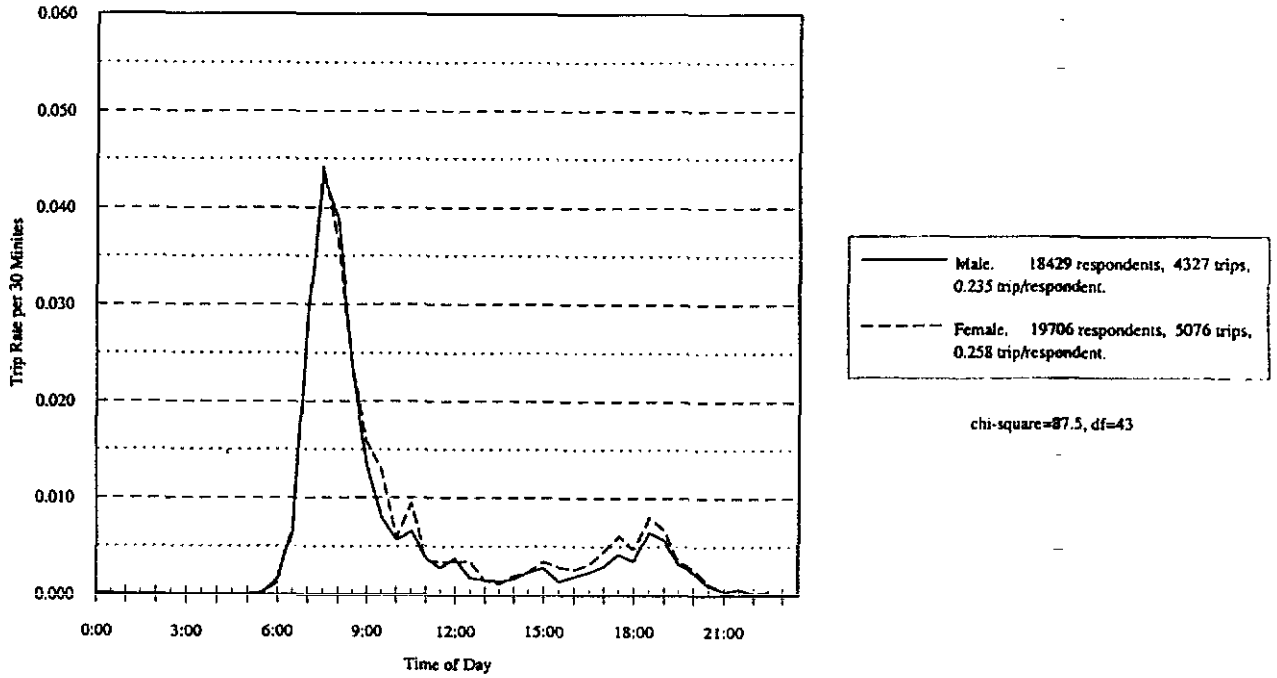


Figure 3.2.e Distribution of Trip Starting Times by Sex: School/church

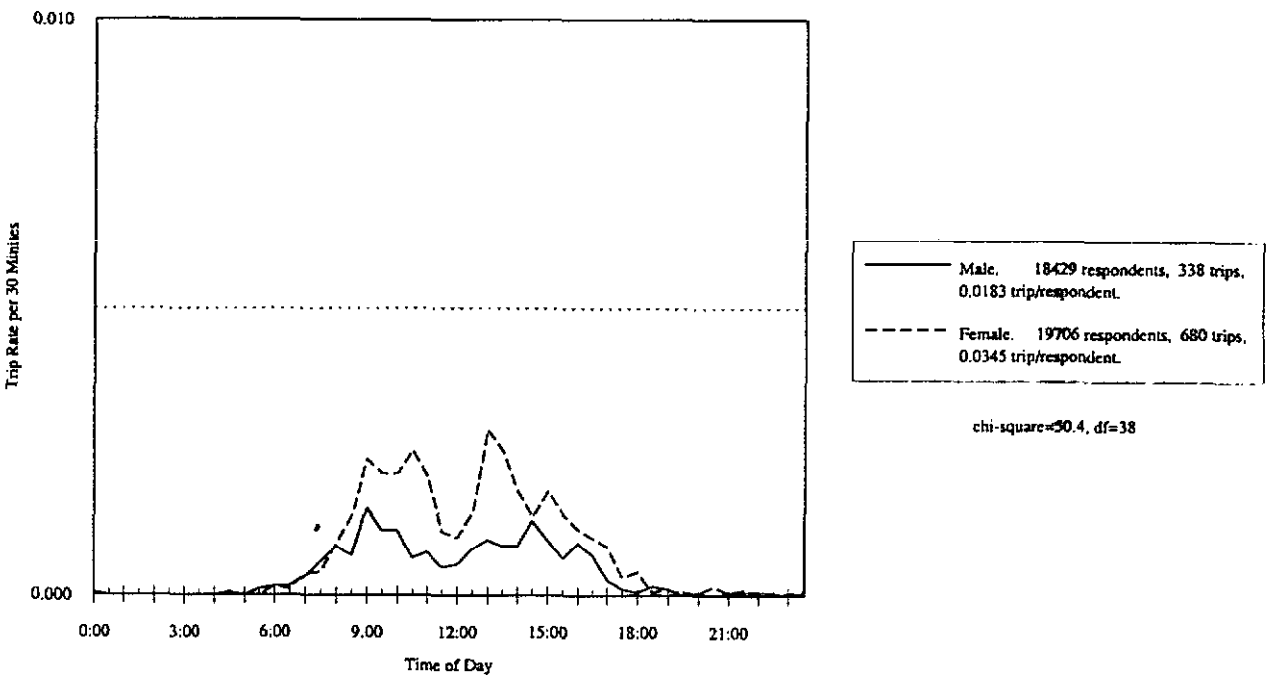


Figure 3.2.f Distribution of Trip Starting Times by Sex: Doctor/dentist

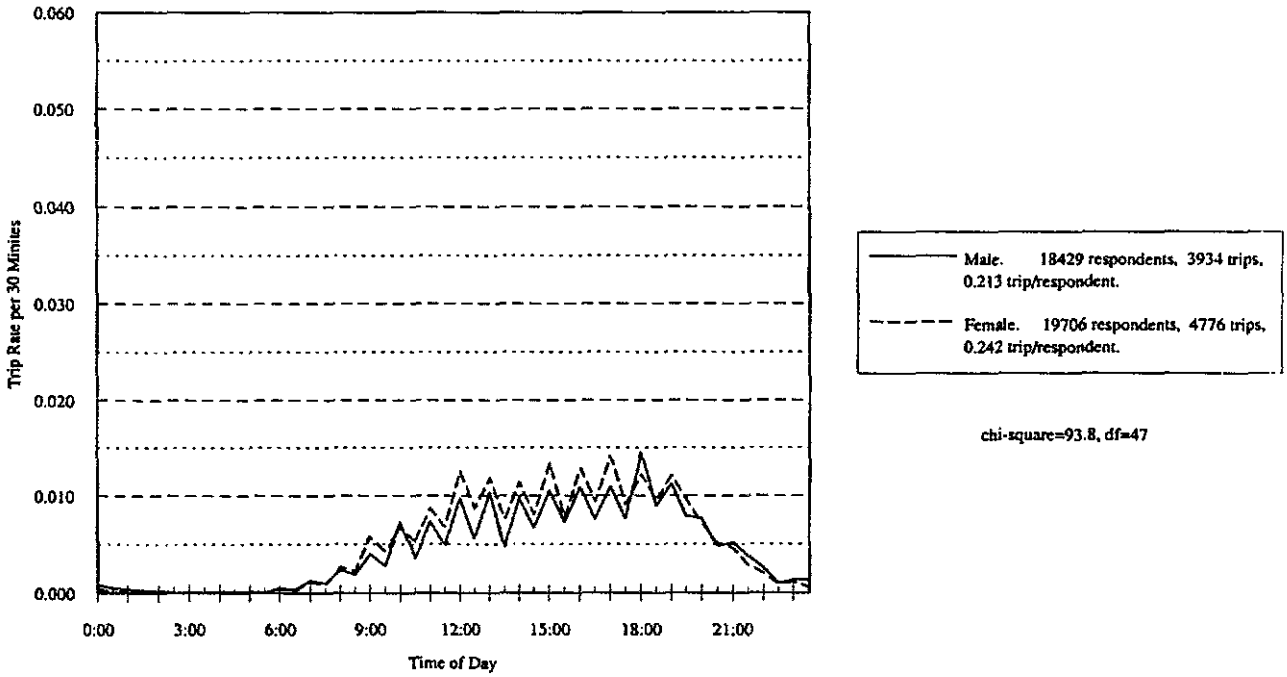


Figure 3.2.g Distribution of Trip Starting Times by Sex: Visit friends or relatives

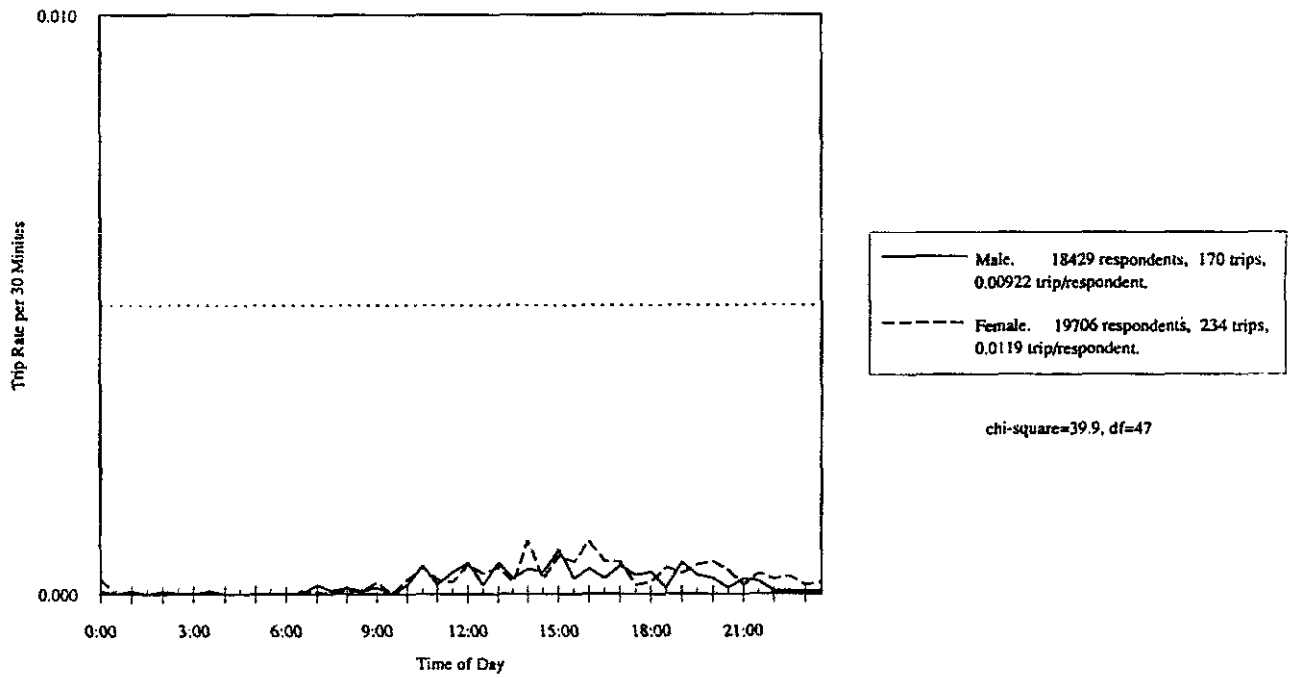


Figure 3.2.h Distribution of Trip Starting Times by Sex: Pleasure driving

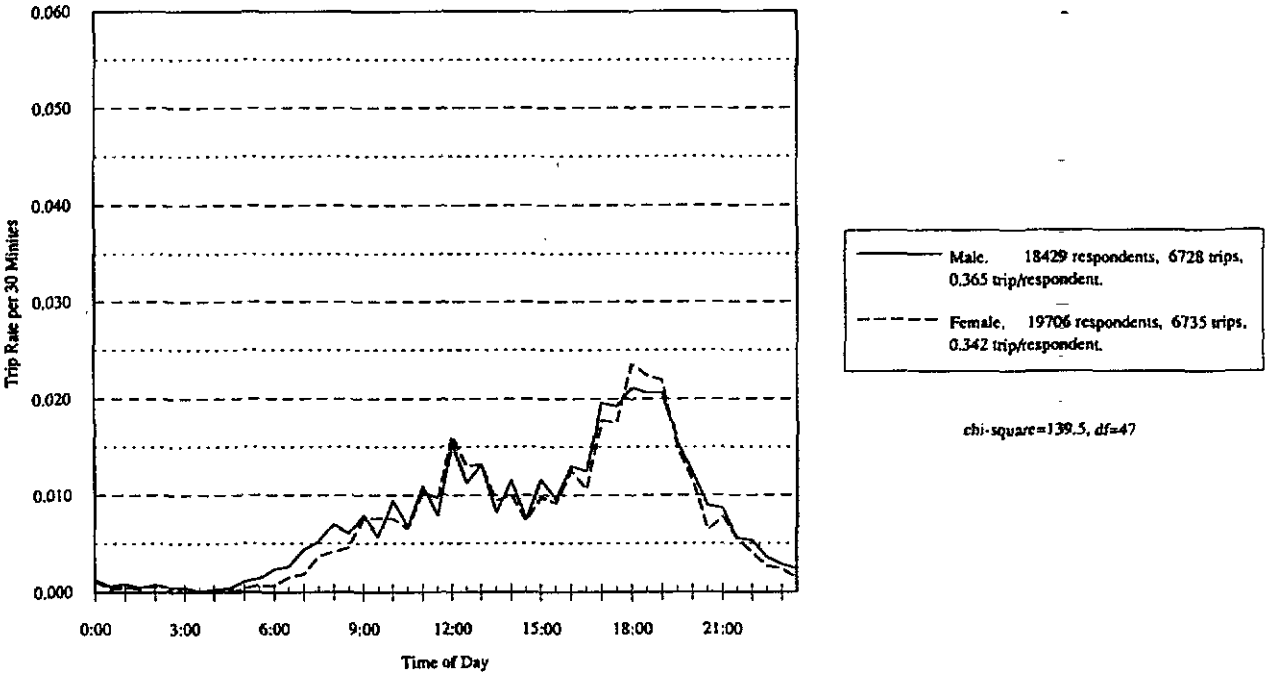


Figure 3.2.i Distribution of Trip Starting Times by Sex: Other social or recreational

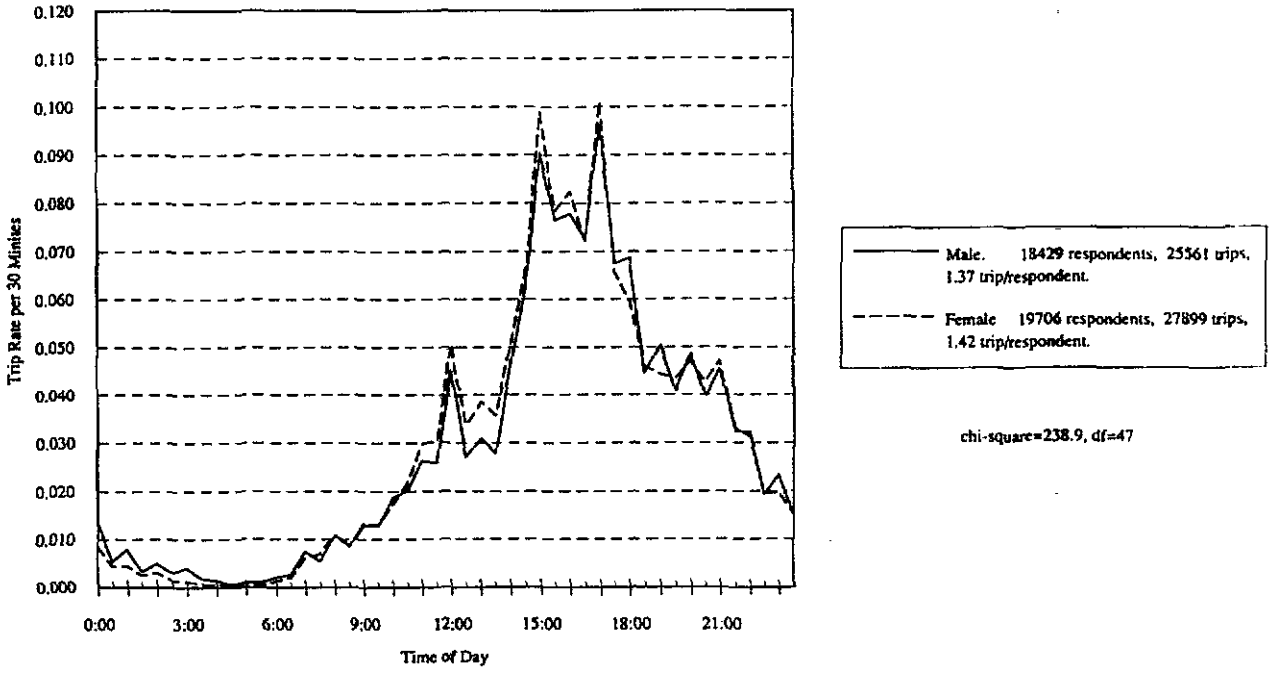


Figure 3.2.j Distribution of Trip Starting Times by Sex: To home

Distribution by Employment

Those who work are subject to tighter time constraints for the very reason that paid-work often commands a significant number of hours per working day. Therefore it can be anticipated that those who work tend to have lower trip rates for non-work activities, especially for discretionary activities. This is more or less true, but not to a very large extent. Appendix Table 3.3 indicates that those who were employed have a mean daily trip rate of 4.126, while those who were not employed have a mean trip rate of 3.635. It can be seen that workers have mean trip rates sightly higher than those of non-workers for shopping and other family or personal business. Non-workers have mean trip rates for social visits and other social and recreational activities that are higher than those of workers, but only slightly. Overall, the indication that workers tend to engage in discretionary activities less frequently is very weak, if at all.

Time constraints due to paid-work, however, substantially affect trip timing. Workers' shopping trips peak in late afternoon around 5:00 p.m., while non-workers' shopping trip rate peaks at 10:00 a.m. and gradually declines toward the evening (Fig. 3.3.a).

For personal business, workers exhibit three peaks: the first around 7:30 a.m. before typical work starting hours, the second during the lunch break, and the third in the 4:00 p.m. to 5:00 p.m. period. The effects of work hours are evident. Note that, because of the trip purpose classification in the NPTS data file, trips made to serve passengers during commute (e.g., taking a child to the day care, or picking up a carpool member) may be included in this "other family or personal business" category.

Figure 3.3.c indicates that the sharp morning peak for school trips is associated with non-workers (presumably full-time students), while workers' school trips have two peaks, one in the morning over the period of 7:30 a.m. to 9:30 a.m., and one in the evening from 5:30 p.m. to 6:30 p.m.

Temporal distribution patterns are quite similar between workers and non-workers for trips made to the doctor's and dentist's (Fig. 3.3.d). The regulating factor is obviously the typical business hours held by doctors and dentists. It can be observed, however, that workers tend to have late afternoon starting times.

Again due to constraints imposed by work schedules, workers trips for social visits and other social or recreational activities tend to cluster in evening hours (Figs. 3.3.e and 3.3.f). In particular, non-workers have highest trip rates for social visits in the 12:00 noon to 4:00 p.m. period, while workers peak lies between 5:00 p.m. and 7:00 p.m. Likewise, workers' evening peak for other social and recreational trips are more pronounced than that for non-workers.

Workers' peak for home trips coincides with the evening peak for homeward commute trips (Fig. 3.3.g). Non-workers' peak, on the other hand, is centered at 3:00 p.m. The higher home trip rates displayed by workers in the evening hours indicate that, again due to constraints from work schedules, workers tend to use the evening period for out-of-home non-work activities more often than do non-workers.

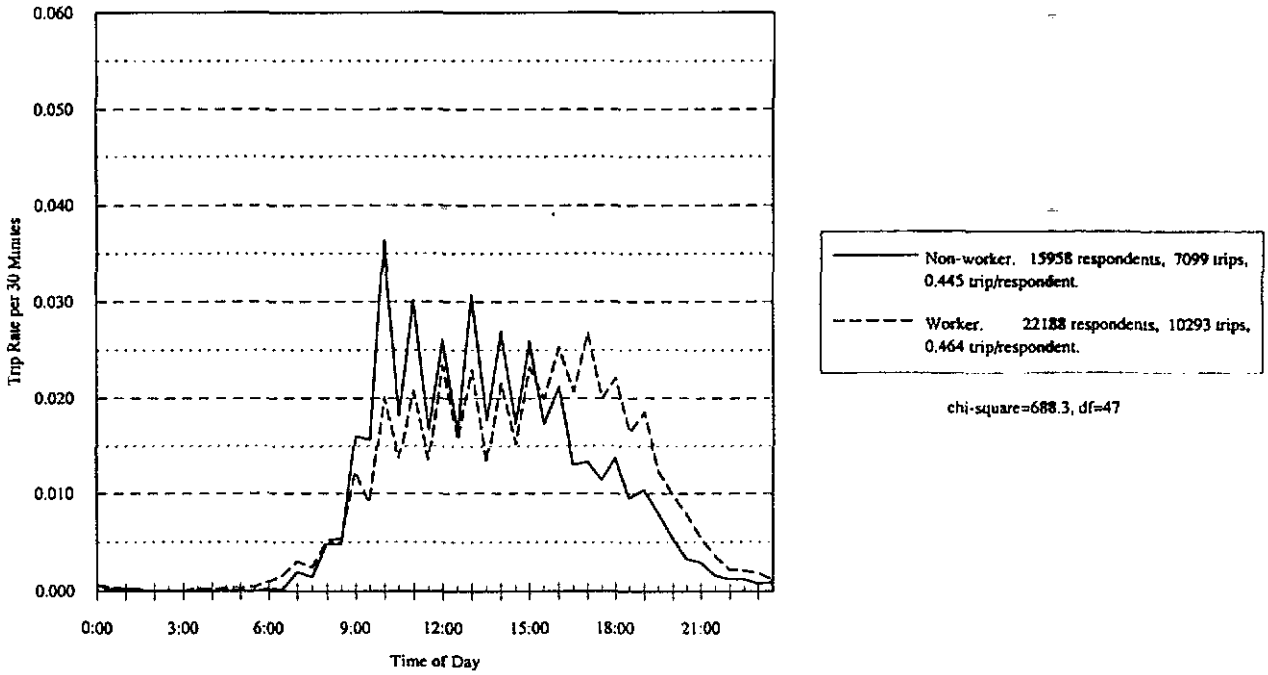


Figure 3.3.a Distribution of Trip Starting Times by Employment: Shopping

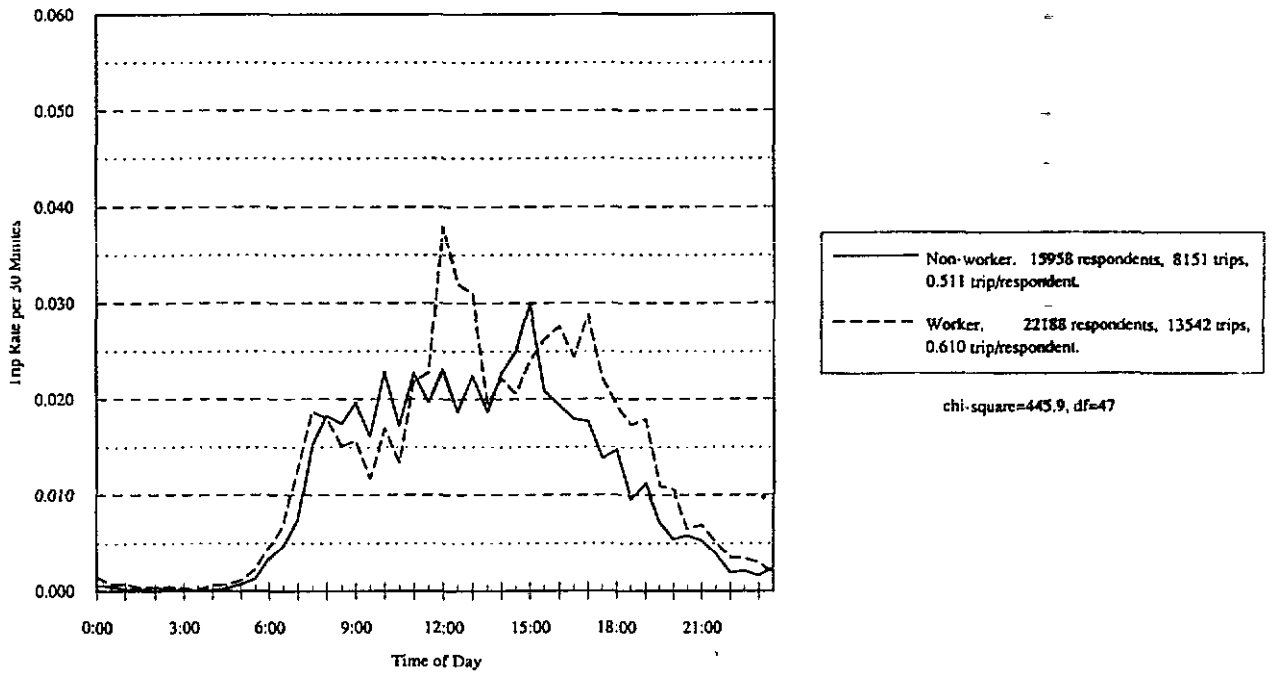


Figure 3.3.b Distribution of Trip Starting Times by Employment: Other family or personal business

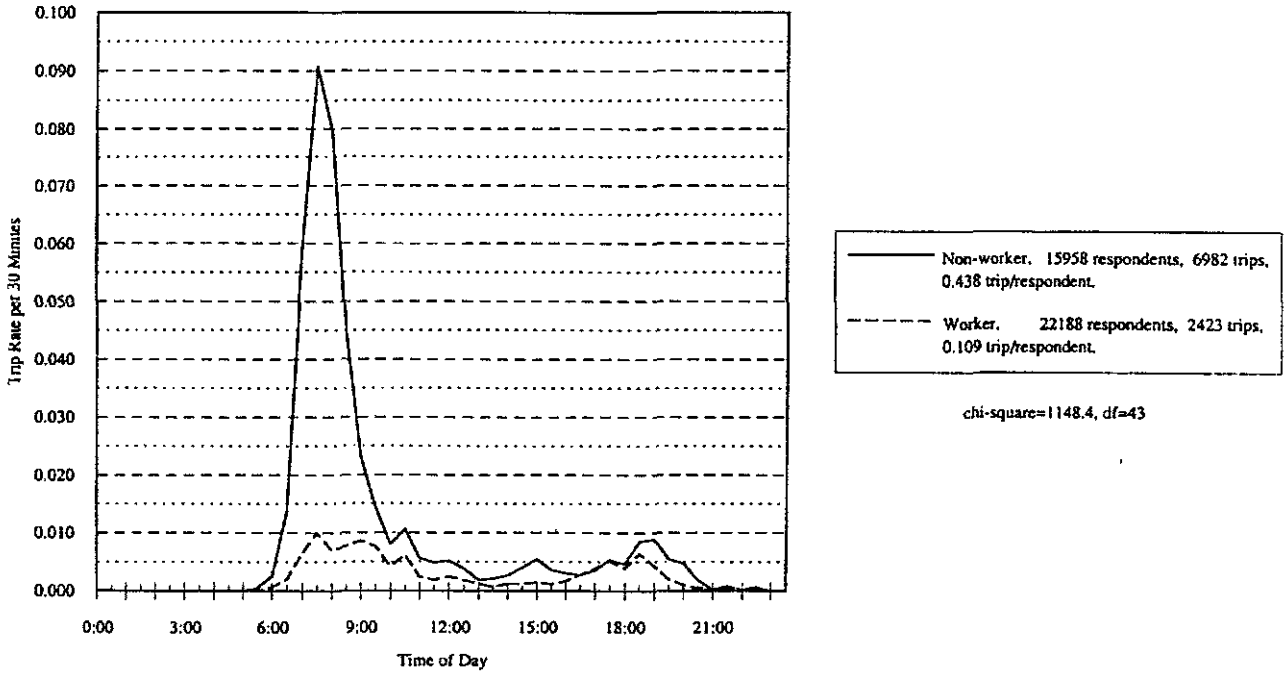


Figure 3.3.c Distribution of Trip Starting Times by Employment: School/church

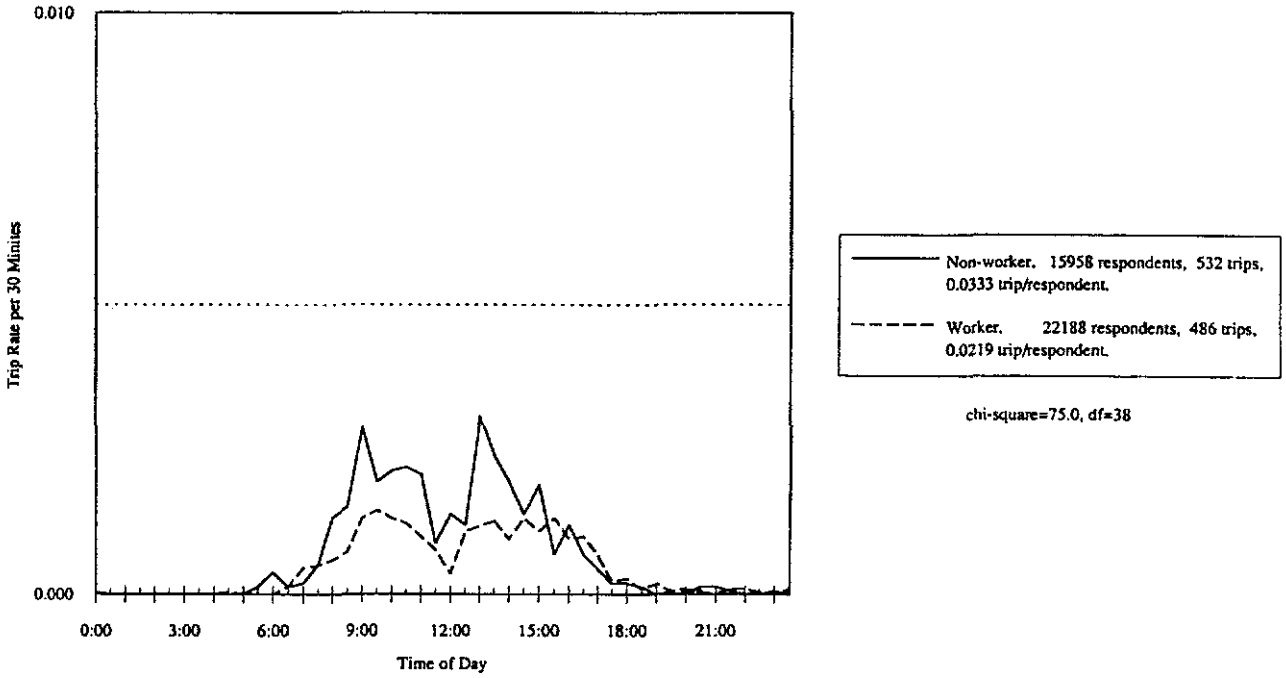


Figure 3.3.d Distribution of Trip Starting Times by Employment: Doctor/dentist

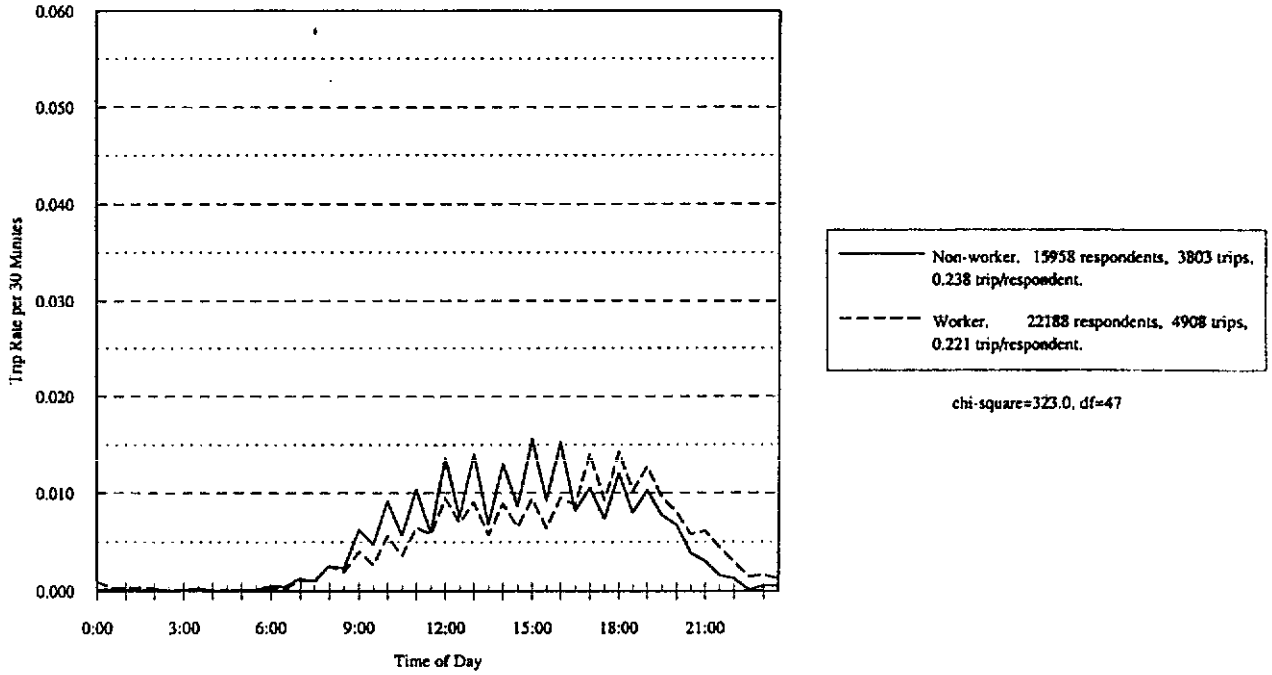


Figure 3.3.e Distribution of Trip Starting Times by Employment: Visit friends or relatives

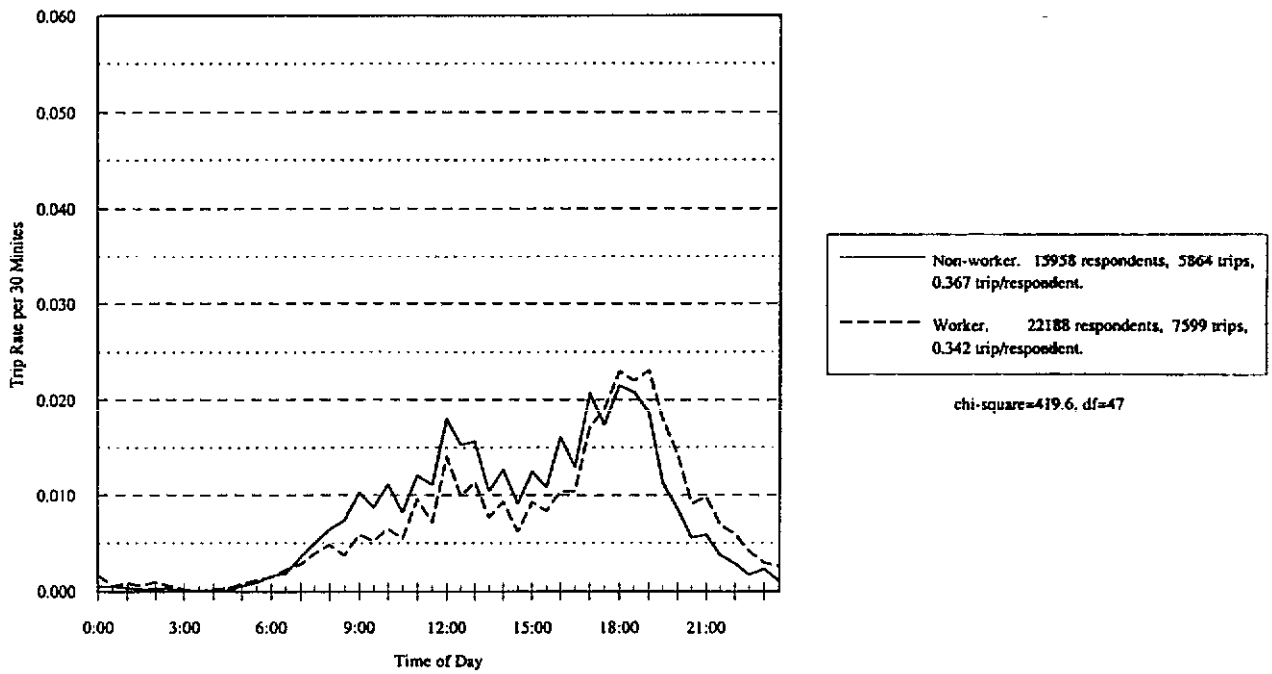


Figure 3.3.f Distribution of Trip Starting Times by Employment: Other social or recreational

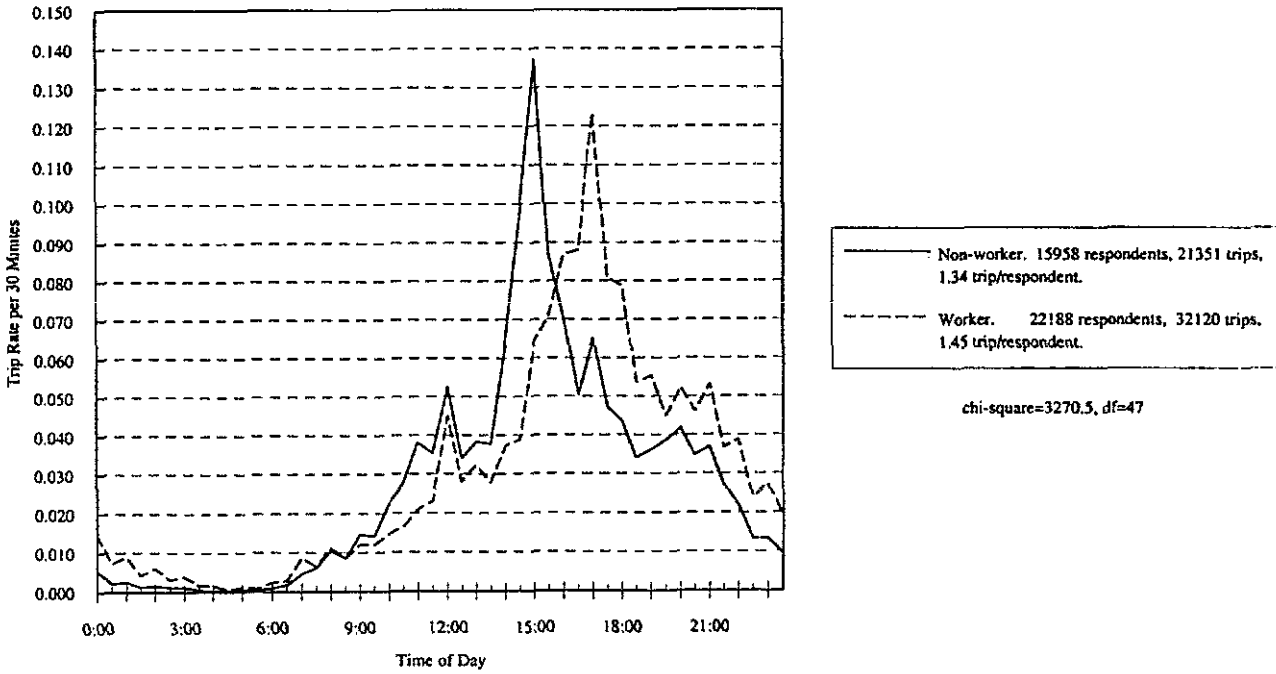


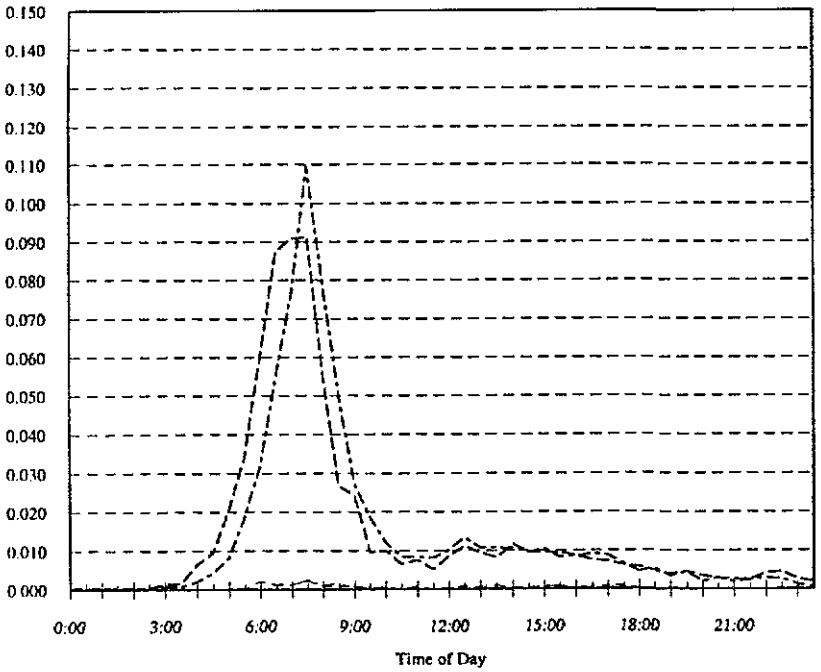
Figure 3.3.g Distribution of Trip Starting Times by Employment: To home

Distribution by Role

An important question that arises here is how the differences in trip rates and trip timing observed above between men and women and between workers and non-workers interact with each other. Are work schedules so dominating a factor in individuals' activity scheduling that there will not be any gender difference given a person is employed? Or are gender differences so persistent that working men's travel patterns are different from working women's patterns? The latter is likely if gender-defined roles are dominant, while the former may be the case if roles are determined primarily by employment. As a step in studying these issues, temporal distributions of trip starting times are now examined by role, defined in terms of gender and employment: non-working men, working men, non-working women and working women.

Trip frequencies and trip rates are summarized by purpose and by role in Appendix Table 3.4. An inspection of the table indicates that the tendencies found earlier for gender groups and employment groups can still be found for the role groups. For example, women, whether employed or not employed, have higher trip rates for shopping and other family or personal business. They also have slightly higher trip rates for social visits and slightly lower rates for other social or recreational purposes than do men, whether employed or not employed. Workers have higher trip rates for shopping and other family or personal business, whether men or women (this is presumably due to the inclusion of minors in the tabulation). Workers also have slightly lower trip rates for social visits and other social or recreational purposes, again whether men or women. Among those who are employed, women have lower trip rates for work and work-related business. Overall, it appears that role effects are produced as a superimposition of employment effects and gender effects.

Differences in work trip peaks can be more clearly seen in Figure 3.4.a where trip rates are computed for workers and non-workers separately. As before, men's work trip peak starts earlier than women's peak, possibly reflecting the trend that men tend to commute to work longer than do women. Trips for work-related business by workers exhibit the same peaking patterns as before, with men having peaks in the morning and afternoon, while women have a peak at noon (Fig. 3.4.b). Likewise, the tendencies found earlier for employment or for gender can in general be found for shopping, other family or personal business, school or church, dental or medical, social visits, and other social or recreational trips (see Figs. 3.4.c through 3.4.j). This is also the case for home trips. In this case employment is the factor that defines the temporal distribution of trips. Given that one is employed or not employed, there are little differences in the temporal distribution of home trips between men and women.



Male, Non-worker. 6688 respondents, 137 trips, 0.0205 trip/respondent.

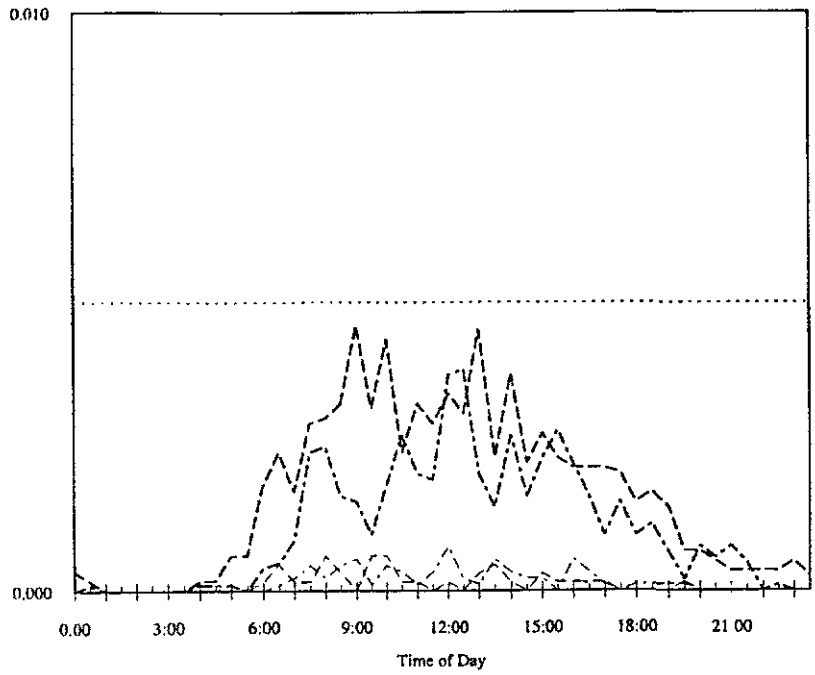
Male, Worker. 11747 respondents, 8261 trips, 0.704 trip/respondent.

Female, Non-worker. 9262 respondents, 183 trips, 0.0198 trip/respondent.

Female, Worker. 10444 respondents, 7031 trips, 0.673trip/respondent.

chi-square=833.2, df=141

Figure 3.4.a Distribution of Trip Starting Times by Role: To work



Male, Non-worker. 6688 respondents, 36 trips, 0.00538 trip/respondent.

Male, Worker. 11741 respondents, 928 trips, 0.0790 trip/respondent.

Female, Non-worker. 9262 respondents, 66 trips, 0.00713 trip/respondent.

Female, Worker. 10444 respondents, 542 trips, 0.0519 trip/respondent.

chi-square=154.5, df=123

Figure 3.4.b Distribution of Trip Starting Times by Role: Work-related business

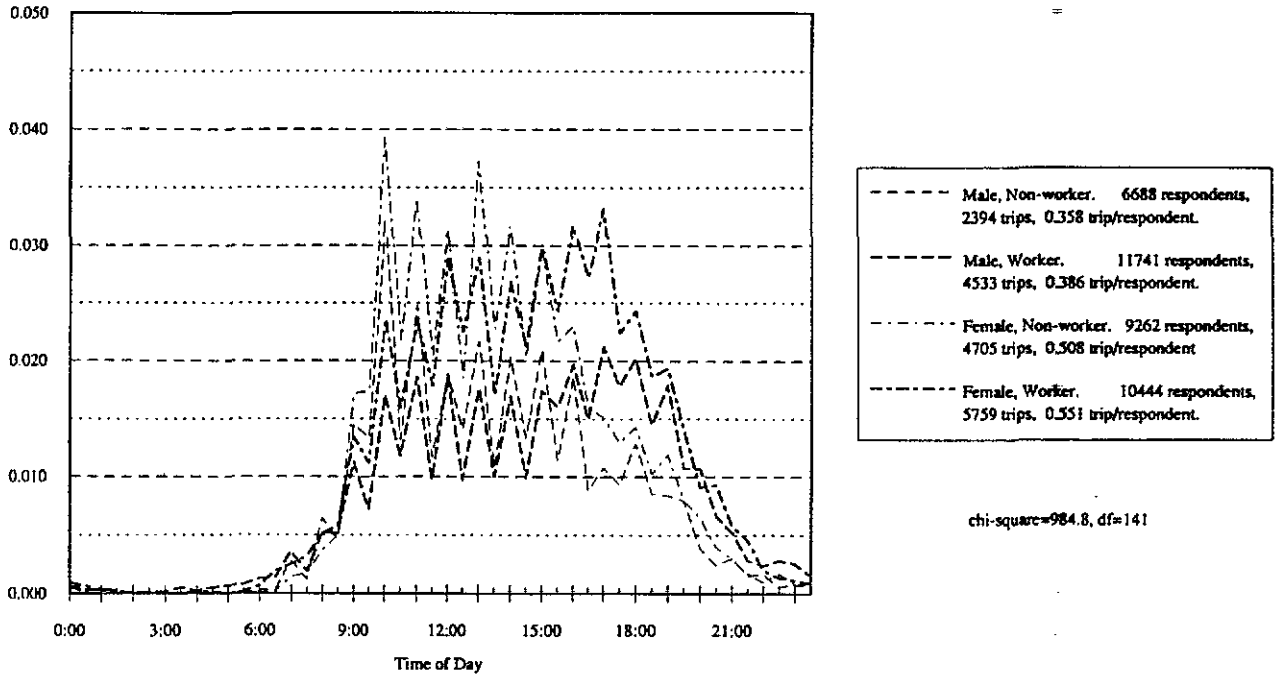


Figure 3.4.c Distribution of Trip Starting Times by Role: Shopping

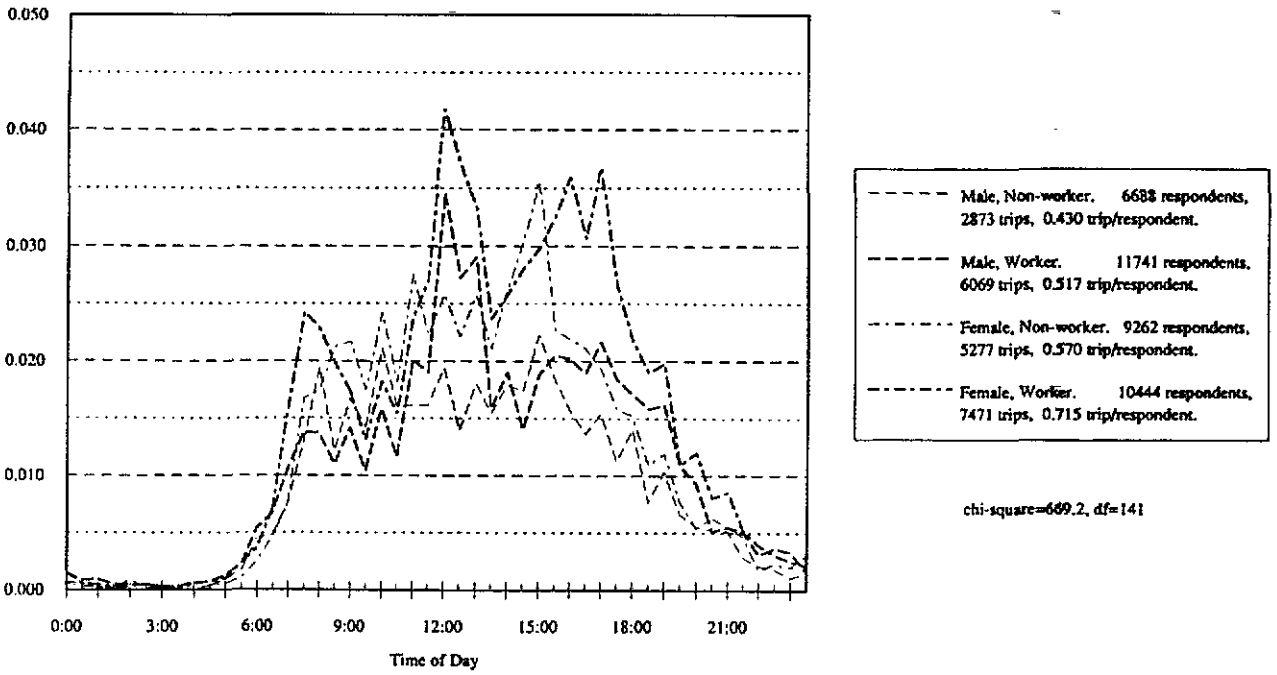
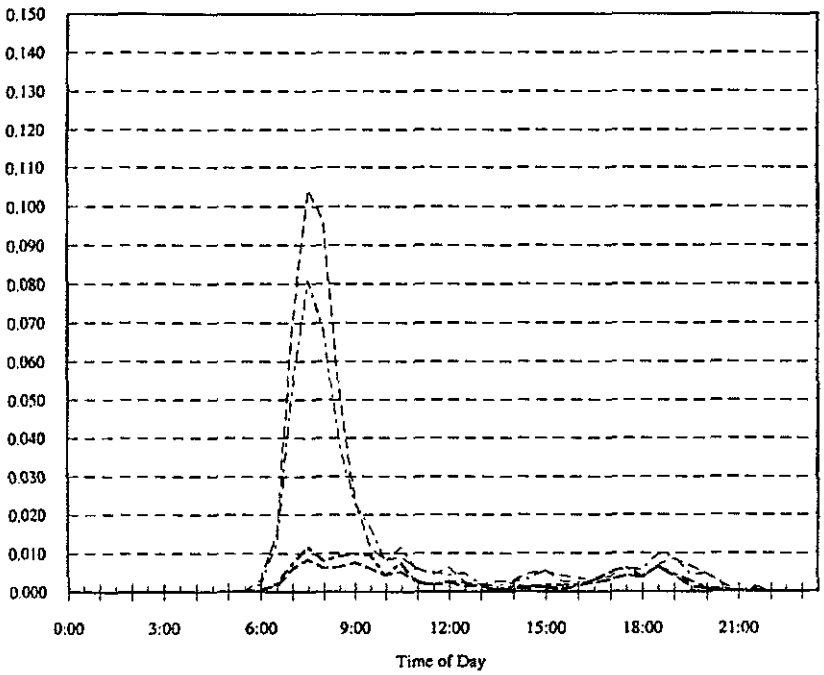


Figure 3.4.d Distribution of Trip Starting Times by Role: Other family or personal business



Male, Non-worker. 6688 respondents, 3202 trips, 0.479 trip/respondent.

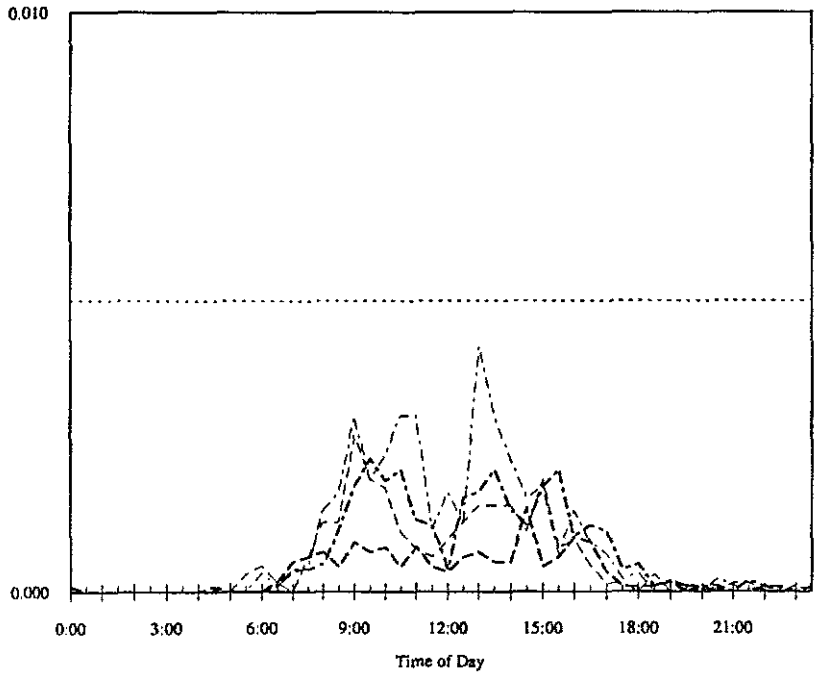
Male, Worker. 11741 respondents, 1125 trips, 0.0958 trip/respondent.

Female, Non-worker. 9262 respondents, 3778 trips, 0.408 trip/respondent.

Female, Worker. 10444 respondents, 1298 trips, 0.124 trip/respondent.

chi-square=1303.9, df=129

Figure 3.4.e Distribution of Trip Starting Times by Role: School/church



Male, Non-worker. 6688 respondents, 169 trips, 0.0253 trip/respondent.

Male, Worker. 11741 respondents, 169 trips, 0.0144 trip/respondent.

Female, Non-worker. 9262 respondents, 363 trips, 0.0392 trip/respondent.

Female, Worker. 10444 respondents, 317 trips, 0.0304 trip/respondent.

chi-square=172.0, df=114

Figure 3.4.f Distribution of Trip Starting Times by Role: Doctor/dentist

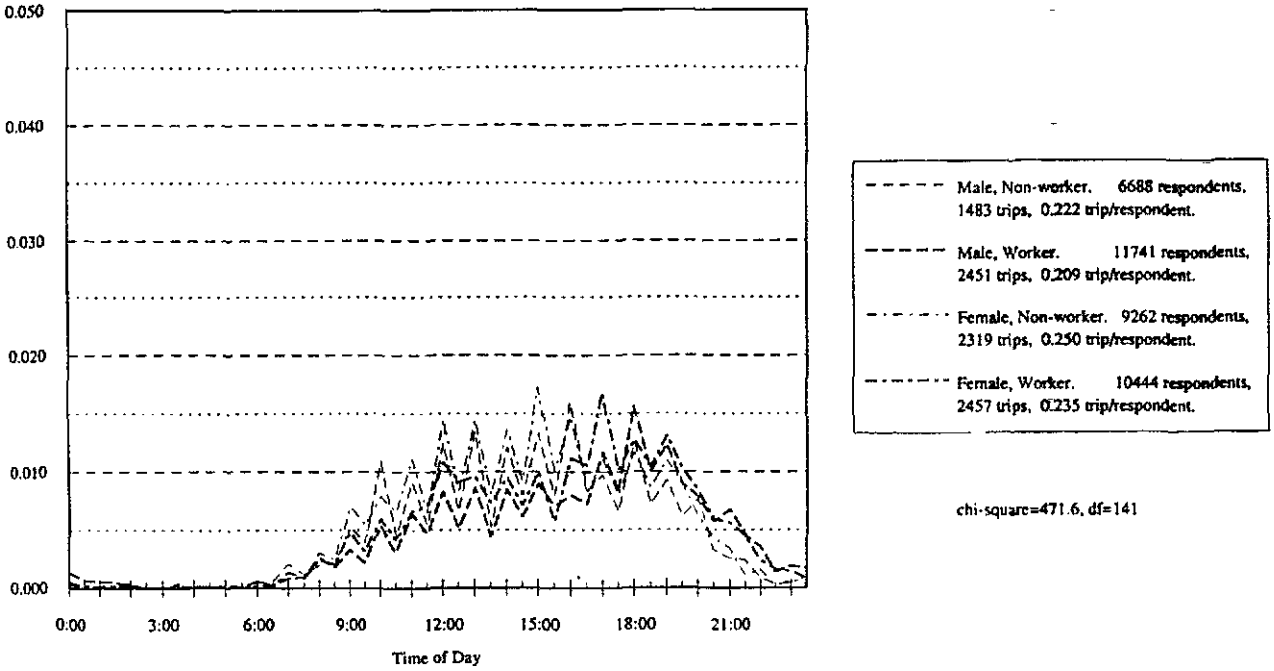


Figure 3.4.g Distribution of Trip Starting Times by Role: Visit friends or relatives

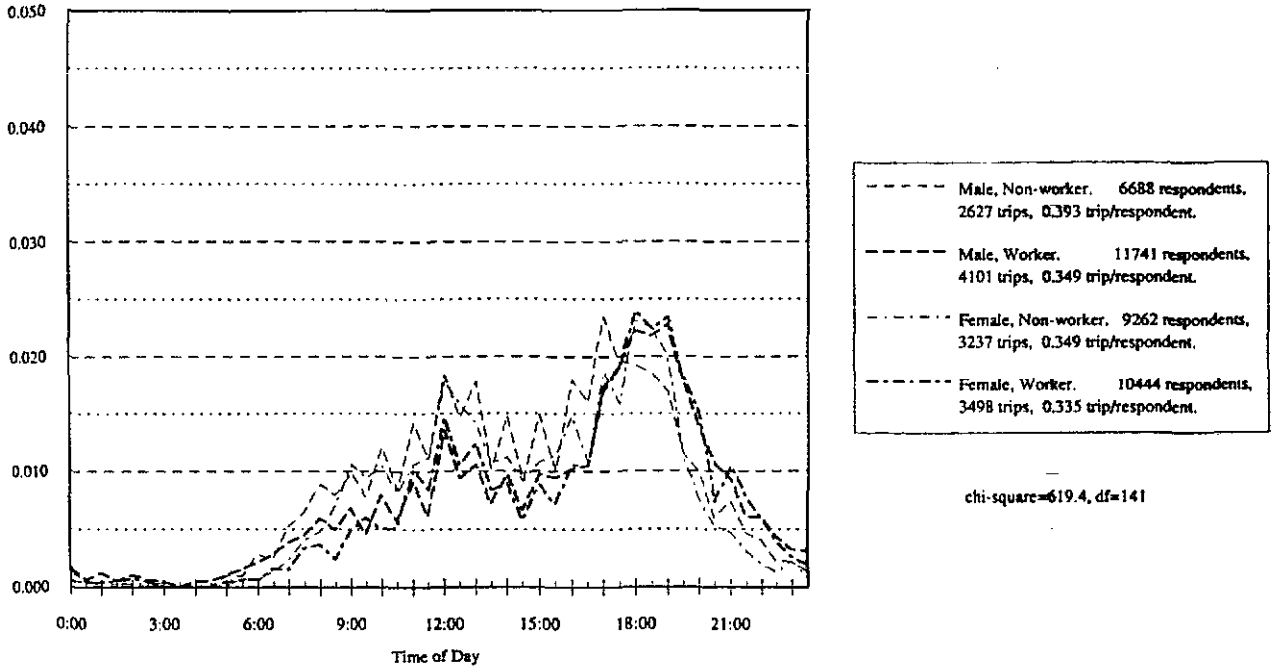


Figure 3.4.h Distribution of Trip Starting Times by Role: Other social or recreational

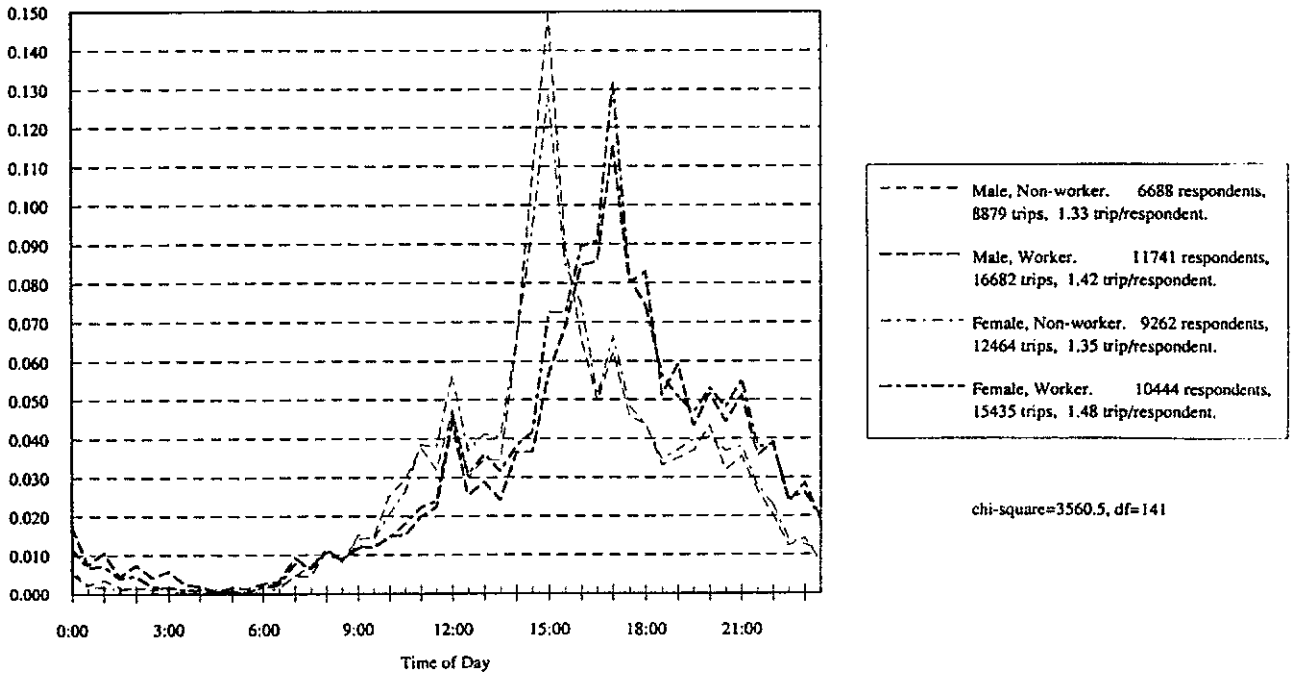


Figure 3.4.i Distribution of Trip Starting Times by Role: To home

4. Conditional Probabilities of Trip Making

As initial steps of modeling travel behavior along the time-of-day axis, the conditional probabilities of out-of-home activity engagement (or trip making) and conditional distributions of trip purposes, given that a trip is made during a specific time interval, are examined in this section. First the distribution of trip purposes is studied by trip starting time over the one-day period. This is followed by an analysis of the conditional probability of trip making for a certain purpose, given that a trip has been made, or has not been made, for the same purpose in the past. The intent of the analysis is to explore the dependence of trip making on past activity engagement.

Distribution of Trip Purposes by Starting Time

Figures 4.1.a - c show the distribution of trip purposes by trip starting time with horizontal bars indicating the relative frequencies of trip purposes within the respective 30-min. intervals. The relative frequency of a trip purpose can be interpreted as the probability that the trip will be made for that purpose, given a trip is made by an individual within the 30-min. interval. Tendencies found in the figure are discussed below for major trip purpose categories.

Work is the predominant purpose during the early morning period of 3:00 a.m. to 8:00 a.m. (note that relative frequencies are evaluated within each time period, and a high relative frequency in one period does not necessarily imply that the number of trips generated in that period is large). The relative frequency of work decreases during the day, then increases again toward 5:00 p.m., presumably reflecting the way purposes of linked trips are coded. School shows similar tendency with different peaks.

The probability of shopping increases toward 10:00 a.m., then very gradually decreases toward the end of the day. Other family or personal business shows similar tendency, but has much larger relative frequencies between 9:00 p.m. and 9:00 a.m. Visiting friends or relatives increases toward midnight, stays at that level till 2:00 a.m., then declines. Other social or recreational purposes have the same tendency, except that their relative frequencies are the highest in the early morning of 1:00 a.m. to 3:00 a.m.

The tendencies found here are consistent with the profiles of activity engagement found from time use data (e.g., Kitamura et al., 1992). The effects of such institutional factors as work and school schedules are evident form the tabulation results. Most notably, work and school purposes are predominant during early morning hours. As the relative shares of trips made for these activities — which tend to be mandatory and quite often fixed in time and space — decline, the shares for more flexible activities increase. Shopping and personal business activities tend to have much larger degrees of flexibility in terms of their location and timing. Trips made for these activities increase as work and school trips decrease their shares. It is notable that personal business trips maintain relatively larger shares throughout the day, even in early morning hours. Shopping trips, on the other hand, are infrequent in these hours.

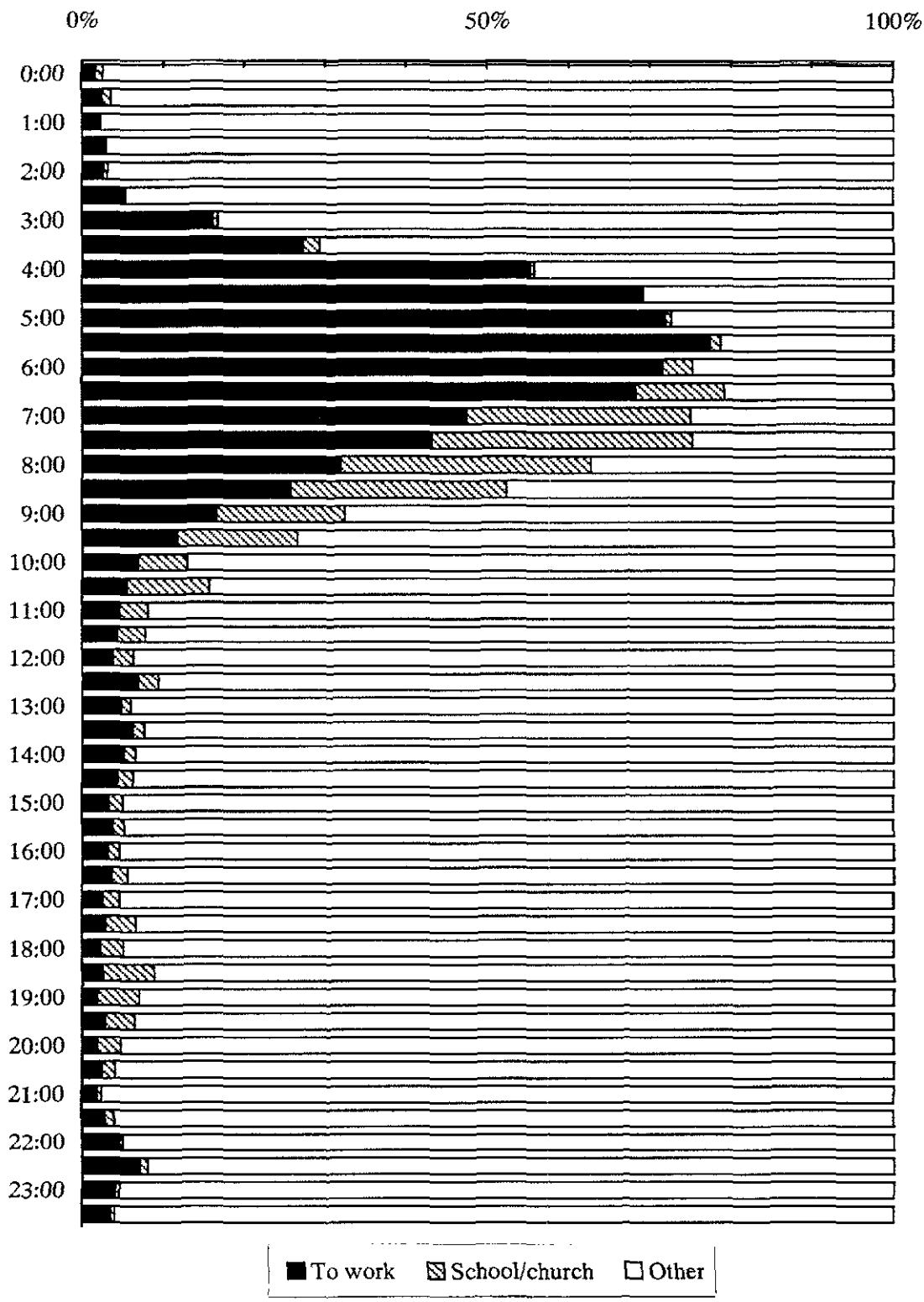


Figure 4.1* Distribution of Trip Purposes by Starting Times

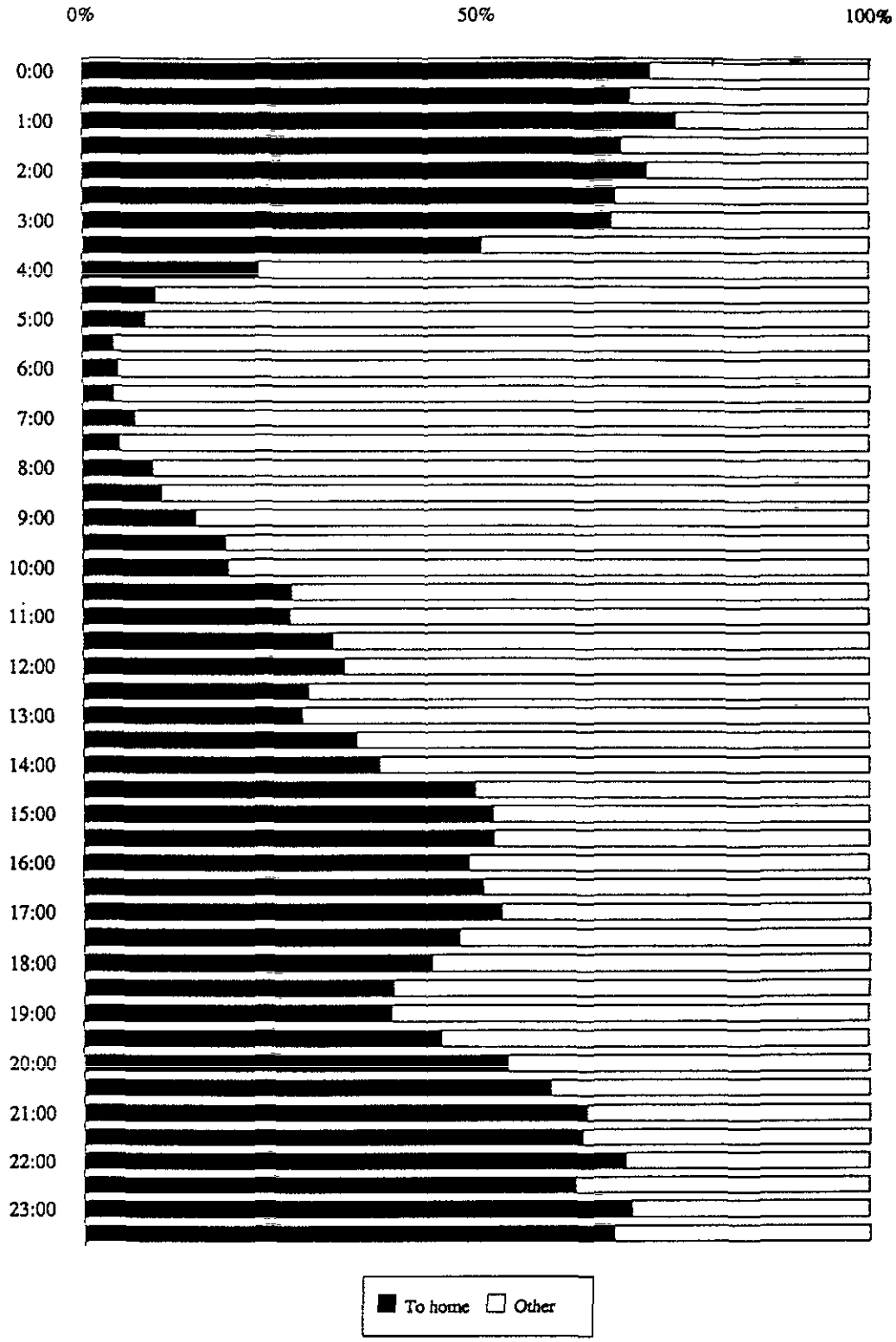


Figure 4.1* Distribution of Trip Purposes by Starting Times

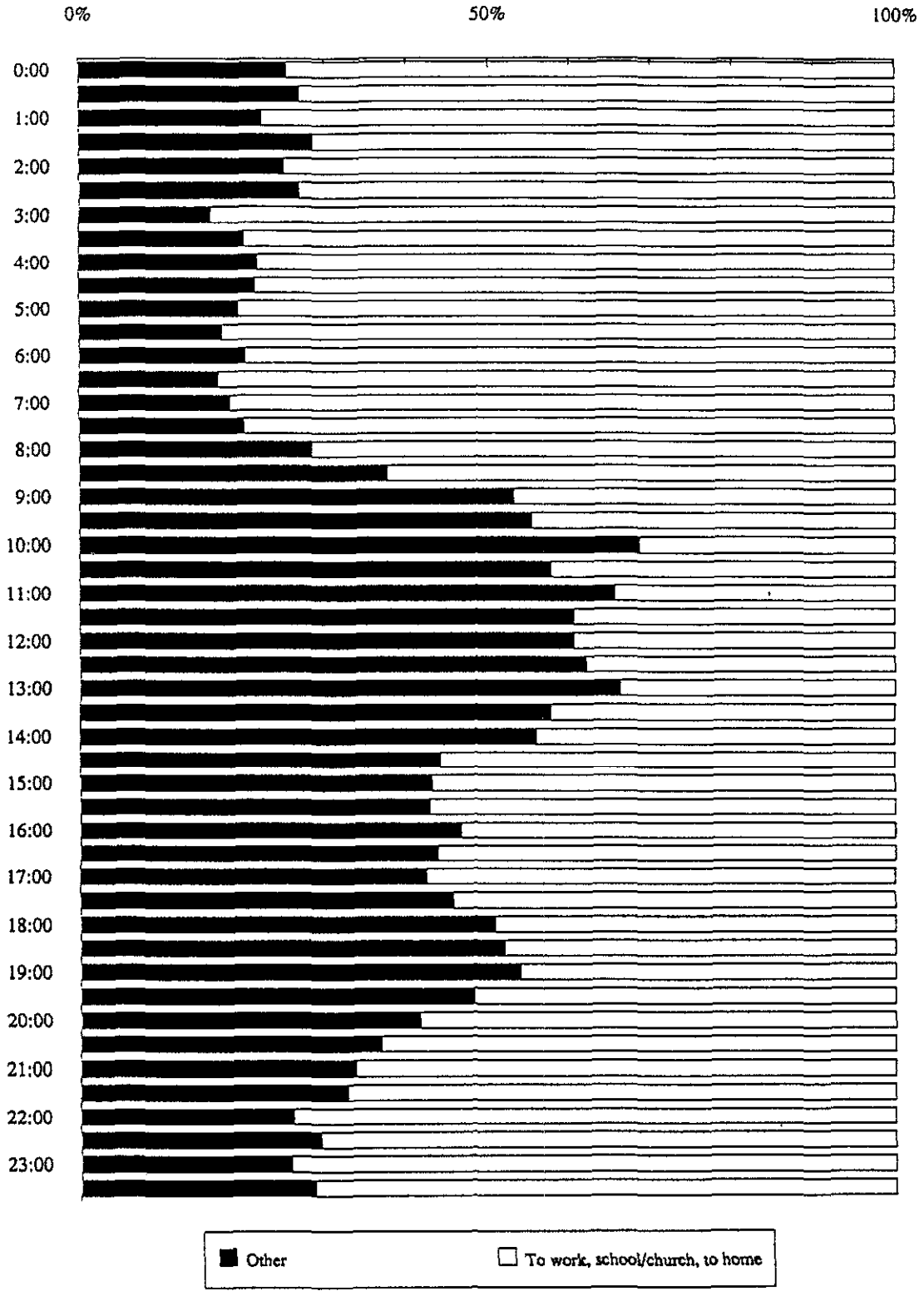


Figure 4.1* Distribution of Trip Purposes by Starting Times

Trips for social visits and other social/recreational activities show some increases in early mornings (8:00 to 9:00 a.m.), and remain at these levels through mid-afternoon. The relative shares of these discretionary activities show marked increases during the "after work" hours. *In fact nearly 50% of all trips made are for* these purposes during the period of 9:00 p.m. and 2:00 a.m.

The distributions of trip purposes by time of the day are consistent with the notion that an individual's daily life is regulated by mandatory activities such as work and school, whose often rigidly fixed schedules tend to work as "pegs" (see Jones et al., 1983) around which other, more flexible activities tend to be scheduled. The results also show that discretionary activities tend to be pursued after more mandatory activities such as work (Kitamura, 1983). Clearly the work/school schedule is a critical factor that regulates an individual's daily activity schedule and trip timing. One important issue for investigation, then, is how discretionary activities are scheduled given work/school schedules. For example, what are the factors that affect whether a person engages in a discretionary activity before or after work? This subject is examined later in this report using the NPTS data.

Conditional Probabilities of Activity Engagement

The analysis now focuses on the conditional probability of engaging in an out-of-home activity (therefore making a trip for that purpose), given the engagement in the past during the day in activities of the same type. The analysis is motivated by the desire to examine the history dependence in activity engagement and is conceived as an initial stage toward the construction of a behavioral model of trip making. In this sense, the effort here shares its objective with Kitamura & Kermanshah (1983, 1984) and Mannering, Murakami & Kim (1994).

A question of particular interest is how the fact of engaging in out-of-home activities of a given type affects the probability of engaging in the same type of activity on the same day. If future activity engagement can be probabilistically described as a function of past activity engagement, then it will be possible to simulate a person's daily activity pattern from a given time point on, using information on activity engagement in the past. More generally, it is crucial for the development of a model of daily activity engagement that the inter-dependence among activities engaged in the course of a day — or possibly over a longer span of time — be properly represented.

Different types of interdependencies are possible among activities. Certain activities may be engaged just once during a day, thus past engagement would almost certainly preclude recurrent engagement in the future. Having lunch is an example. Other types of activities, on the other hand, may have the tendency that past engagement leads to higher probabilities of engagement in the future. Shopping around for a durable good is an example.[1]

The NPTS data set is used here to probe these issues. Three activity types — shopping, other family and personal business, and other social or recreational activities — are used in the analysis. Conditional probabilities of engaging in these activities in the future, given the engagement in activities of the same type in

[1]It is possible that this apparent past dependence is spurious, merely reflecting the higher propensity to engage in that type of activity which the individual possesses. This is the case of true state dependence versus heterogeneity. Pursuing this issue in the context of activity engagement is a task for future research.

the past, are evaluated at three time points of the day, 12:00 noon, 3:00 p.m. and 6:00 p.m. Results are summarized in Table 4.1, where each entry represents the conditional probability of engaging (E) or not engaging (N) in the activity of the same time given past engagement.

The conditional probabilities evaluated at three time points display the clear tendency that the probability of engaging in an out-of-home activity decreases as the day progresses, irrespective of past activity engagement. This is not at all a surprising result as the chance of pursuing an activity will decrease as the time that remains during a day decreases. Social and recreational activities, which the analysis of the previous section revealed as dominant activities during the evening period, show the weakest tendency of this type.

The conditional probabilities evaluated for shopping show that past engagement in shopping does not affect future engagement. The conditional probabilities shown in the first row (given past engagement) and those in the second row (given non-engagement) are surprisingly similar. Shopping engagement appears to be history independent. Its engagement probability, however, is dependent on the time of day with its value decreasing from over 0.25 at 12:00 noon to less than 0.08 at 6:00 p.m.

Conditional probabilities for both other family or personal business and other social or recreational activities indicate strong history dependence, with engagement probabilities much greater in the case of past engagement than in the case of non-engagement. This is more pronounced for other family or personal business. For example, as of 12:00 noon, the probability of engaging in this activity in the future is 0.486, given that family or personal business has been pursued by then, but the probability is only 0.205 given that no such activity has been engaged. The corresponding values evaluated as of 3:00 p.m. are 0.302 versus 0.131, and at 6:00 p.m. 0.134 versus 0.054.

Table 4.1: CONDITIONAL PROBABILITIES OF ACTIVITY ENGAGEMENT BY PAST ENGAGEMENT AND TIME OF DAY

a. Shopping

Past Engagement	At 12:00 Noon			At 3:00 P.M.			At 6:00 P.M.		
	E	N	Total	E	N	Total	E	N	Total
Engaged (E)	0.257	0.743	1.000	0.157	0.843	1.000	0.069	0.931	1.000
Not Engaged (N)	0.256	0.744	1.000	0.177	0.823	1.000	0.079	0.921	1.000
Total	0.256	0.744	1.000	0.173	0.827	1.000	0.076	0.924	1.000

b. Other Family or Personal Business

Past Engagement	At 12:00 Noon			At 3:00 P.M.			At 6:00 P.M.		
	E	N	Total	E	N	Total	E	N	Total
Engaged (E)	0.486	0.514	1.000	0.302	0.698	1.000	0.134	0.866	1.000
Not Engaged (N)	0.205	0.795	1.000	0.131	0.869	1.000	0.054	0.946	1.000
Total	0.244	0.756	1.000	0.167	0.823	1.000	0.076	0.924	1.000

c. Other Social or Recreational

Past Engagement	At 12:00 Noon			At 3:00 P.M.			At 6:00 P.M.		
	E	N	Total	E	N	Total	E	N	Total
Engaged (E)	0.375	0.625	1.000	0.267	0.733	1.000	0.167	0.833	1.000
Not Engaged (N)	0.200	0.800	1.000	0.154	0.846	1.000	0.092	0.908	1.000
Total	0.211	0.789	1.000	0.167	0.833	1.000	0.105	0.895	1.000

The result found for family or personal business and social or recreational activities that conditional engagement probabilities are greater given that activities of the same type have been engaged in the past implies that individuals tend to be split into two groups, one of which consisting of those who do not engage in these activities at all, and the other consisting of those who engage in them multiple times in the course of the day. Obviously properly capturing these history dependencies is critically important for model development.

Before closing this section, it is important to note that the analysis here represents an initial cursory exploration of the data set regarding the history dependence of activity engagement. Only the frequency of trips by time of day is considered in the analysis and the attributes of individuals and other possible contributing factors are not incorporated into the analysis. In particular, the issue of history dependence versus heterogeneity noted earlier in a footnote of this report remains to be explored in the future. Furthermore, history dependence is examined only within the same type of activity while dependencies across different types of activities have not been examined. Nonetheless, this initial analysis has made evident that the dependence of activity engagement on the time of day and on its own history must be explicitly incorporated into the analysis of activity engagement and trip making.

5. Model Systems of Activity Timing and Duration

Many factors are conceivable as ones that affect the timing of out-of-home activities, therefore the timing of trips made for them. Among them is the duration of an intended activity. If the intended activity takes a substantial amount of time, then it will be engaged when a time block of sufficient length is available. This is the case where activity duration determines activity timing. On the other hand, there may be cases where the length of an intended activity is adjusted such that it can be pursued within an available block of time. In this case activity timing determines activity duration. In reality both relationships co-exist and define activity engagement. As an initial attempt to examine causal relationships involving activity duration and timing, alternative structural models are developed and estimated using the NPTS data set.[1] The analysis of this section considers only shopping activity engagement by workers, and adopts for simplicity a binary indicator of activity timing, i.e., whether shopping activity is pursued before work or after work.[2]

Let i denote the individual; T_i be the timing of the shopping activity and let $T_i = -1$ if it takes place before work, and $T_i = 1$ if it takes place after work; T^*_i be a latent variable underlying T_i; D_i be the duration of the shopping activity; α, β, γ, and μ be vectors of coefficients; θ and κ be scalar coefficients; X_i and Z_i be vectors of explanatory variables; and (ε_i, ξ_i) and (ζ_i, η_i) be bi-variate normal random vectors. Then the model systems of this section can be presented as follows:

Timing-Duration Model System

$$T^*_i = \alpha' X_i + \varepsilon_i$$

$$T_i = -1 \text{ if } T^*i \le 0;$$

$$1 \text{ if } T^*_i > 0$$

$$D_i = \beta' Z_i + \theta T_i + \xi_i$$

Duration-Timing Model System

$$Di = \gamma' Z_i + \zeta_i$$

$$T^*_i = \mu' X_i + \kappa D_i + \eta_i$$

$$T_i = -1 \text{ if } T^*_i \le 0;$$

$$1 \text{ if } T^*_i > 0$$

The systems each consist of two model components, a binary timing model and a duration model. The variables that appear in the model systems are summarized in Table 5.1.

Two alternative models developed in the study are summarized in Table 5.2. A positive coefficient of a variable in the timing model component implies that a greater value of the variable contributes to the prob-

---

[1]Damm (1982) estimated a model system of activity timing and duration, where activity duration is conditioned on activity timing. This study extends this previous effort by examining the reverse conditionality as well.

[2]The sample used here is obviously a self-selected subset of individuals who commuted and engaged in shopping on the survey day. Addressing possible selectivity bias arising from this is outside the scope of the analysis presented here.

ability that the activity will be pursued after work. In the timing-duration model system (in which the timing of the shopping activity is assumed to affect its duration), work starting time (WORKSTART) is the most significant variable indicating that the later is the work start time, the more likely will shopping be pursued before work. The timing model also indicates that those who commute by auto tend to engage in shopping after work (DRIVE); residents in non-urban area (NONURBAN) and individuals from larger households (HHSIZE) tend to shop before work; and women tend to shop after work (FEMALE).

Table 5.1: DEFINITION OF VARIABLES USED IN THE MODEL SYSTEM

Variable	Definition
AGE	Age in years
INCOME	Midpoint of household annual income category, in dollars
HHSIZE	Number of persons in household
NONURBAN	1 if household is not in urbanized area; 0 otherwise
FEMALE	1 if respondent is female; 0 otherwise
DRIVE	1 if auto mode is used to travel to work; 0 otherwise
COMMTIME	Commute trip length, in minutes
WORKSTART	Work starting time, in minutes from 4:00 a.m.
SHOPDIST	Shopping trip distance, in miles
PARTYSIZE	Number of persons participated in the shopping trip
WEEKDAY	1 if survey day is a weekday; 0 otherwise
TIMING	-1 if shopping took place before work; 1 otherwise
DURATION	Duration of shopping activity, in minutes

Consistent with the finding of Section 3, the duration model indicates that women tend to have longer shopping durations (FEMALE), while durations tend to be shorter on weekdays (WEEKDAY). The length of the shopping trip (SHOPDIST) and the party size (PARTYSIZE) are also significant and positively contribute to the shopping duration. The respondent's age (AGE) and annual household income (INCOME) turned out insignificant. The coefficient of the timing variable (TIMING) is positive but not significant at $\alpha = 0.05$ in the duration equation, implying that, given the other contributing factors, shopping activity duration is independent of when it is pursued.

The estimated duration-timing model system is presented in Table 5.3. The model coefficients are in general consistent between the two model systems. WORKSTART is again the dominant variable in the timing model while FEMALE is very significant in the duration model. An important differences is that the day of the week (WEEKDAY) is only marginally significant in the duration-timing model system. The coefficient of the shopping duration (DURATION) is positive and highly significant in the timing model, indicating that if the duration of shopping activity is longer, then it tends to be pursued after work.

A comparison of the goodness-of-fit statistics indicates that the timing-duration model system fits the data better. The estimation results thus suggest that workers tend to decide when to shop first, then adjust the duration of shopping. The timing variable is not significant in the shopping duration model of this model system, however. Thus shopping duration may not be "adjusted" at all. The duration-timing model system, on the other hand, offers the indication that shopping duration does influence the decision of when to shop. These apparently conflicting results indicate the needs for further investigation into the causal structures underlying activity timing and duration decision. In particular, the current study is subject to

several limitations and its results should be viewed as preliminary. For example, the covariance of the error terms of the two model components (σTD^2) is set to zero in the duration-timing model because otherwise the coefficient of DURATION turned out to be negative in the timing model. The model systems do require further refinement. Nevertheless, the analysis of this section has seen that the NPTS data can be used to explore the causal mechanisms underlying activity timing and duration.

Table 5.2: TIMING-DURATION MODEL SYSTEM

Variable	Timing Model		Duration Model	
	Coef.	t	Coef.	t
TIMING			0.079	1.29
DRIVE	0.130	3.98		
COMMTIME	0.045	1.52		
WORKSTART	-0.614	-19.84		
AGE	0.049	1.59	0.009	0.24
INCOME	0.049	1.56	0.044	1.19
HHSIZE	-0.057	-1.87		
NONURBAN	-0.085	-2.83		
FEMALE	0.087	2.60	0.178	4.70
SHOPDIST			0.080	2.15
PARTYSIZE			0.098	2.61
WEEKDAY			-0.148	-3.96
σ_T^2	0.586	18.10		
σ_D^2			0.901	16.77
σ_{TD}^2	0.166	3.59		
R.M.S.	0.027			
χ^2	73.28 (7)			
Coef. of Det.	0.479			
N = 667				

Table 5.3: DURATION-TIMING MODEL SYSTEM

Variable	Timing Model Coef.	t	Duration Model Coef.	t
DURATION	0.197	6.64		
DRIVE	0.123	3.78		
COMMTIME	0.042	1.45		
WORKSTART	-0.612	-20.38		
AGE	0.049	1.64	0.017	0.43
INCOME	0.040	1.32	0.046	1.20
HHSIZE	-0.059	-1.96		
NONURBAN	-0.089	-3.01		
FEMALE	0.048	1.45	0.190	4.96
SHOPDIST			0.109	2.82
PARTYSIZE			0.094	2.42
WEEKDAY			-0.062	-1.63
σ_T^2	0.549	18.10		
σ_D^2			0.926	18.10
σ_{TD}^2				
R.M.S.	0.028			
χ^2	83.14 (8)			
Coef. of Det.	0.468			
N = 667				

6. Conclusion

Temporal distributions of trips were examined in this study using the 1990 NTPS data file. The analysis by trip purpose and sample sub-groups have revealed characteristics of trip making that along the time of day. The study has also probed into the issues of history dependence in activity engagement and trip making, and the causal relationships between activity timing and duration. Although the analyses are rather preliminary in their nature, they have shown important future directions of research.

References

Abu-Eisheh, S.A. and F.L. Mannering (1987) Discrete/continuous analysis of commuters' route and departure time choices. *Transportation Research Record,* **1138,** 27-34.

Chang, G.-L., H.S. Mahmassani & M.L. Engquist (1989) System-optimal trip scheduling and routing in commuting networks. *Transportation Research Record,* **1251,** 54-65.

Damm, D. (1982) Parameters of activity behavior for use in travel analysis. *Transportation Research,* **16A**(2), 135-148.

Jones, P.M., M.C. Dix, M.I. Clarke & I.G. Heggie (1983) *Understanding Travel Behaviour.* Gower Publishing, Aldershot, UK.

Kitamura, R. (1983) A sequential, history dependent approach to trip chaining behavior. *Transportation Research Record,* **944,** 13-22.

Kitamura, R. & P.H.L. Bovy (1987) Analysis of attrition biases and trip reporting errors for panel data. *Transportation Research,* **21A**(4/5), 287-302.

Kitamura, R. & M. Kermanshah (1983) Identifying time and history dependencies of activity choice. *Transportation Research Record,* **944,** 22-30.

Kitamura, R. & M. Kermanshah (1984). A sequential model of interdependent activity and destination choices. *Transportation Research Record,* **987,** 81-89.

Kitamura, R., J. Robinson, T.F. Golob, M. Bradley, J. Leonard & T. van der Hoorn (1992) A comparative analysis of time use data in the Netherlands and California: Effects of commute times and store operating hours on travel and activity patterns. *Proceedings of Seminar E, 20th PTRC Summer Annual Meeting,* PTRC Education and Research Services Ltd., London, pp. 127-138.

Mannering, F., E. Murakami & S.-G. Kim (1994) Temporal stability of travelers' activity choice and home-stay duration: Some empirical evidence. *Transportation* (forthcoming).

Purvis, C.L. (1984) Changes in regional travel characteristics and travel time budgets in the San Francisco Bay Area: 1960 - 1990. Presented at the 73rd Annual Meeting of the Transportation Research Board, Washington, D.C., January.

Appendix Tables

Appendix Table 3.1: TRIP FREQUENCY AND TRIP RATE BY PURPOSE BY AGE

Purpose	16 - 24		25 - 34		35 - 49		50 - 64		≥ 65		Total	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Work	2443	0.454	4523	0.601	5688	0.607	2418	0.459	282	0.106	15354	0.508
Work-related business	134	0.025	400	0.053	719	0.077	246	0.047	46	0.017	1545	0.051
Shopping	2124	0.394	3924	0.521	5026	0.537	2680	0.509	1509	0.568	15263	0.505
Other family or personal business	2809	0.522	5383	0.715	6717	0.717	2732	0.519	1282	0.483	18923	0.627
School/church	1790	0.332	791	0.105	987	0.105	533	0.101	344	0.130	4445	0.147
Doctor/dentist	83	0.015	190	0.025	256	0.027	204	0.039	111	0.042	844	0.028
Vacation	14	0.003	31	0.004	60	0.006	13	0.002	12	0.005	130	0.004
Visit friends or relatives	2136	0.397	1998	0.265	1610	0.172	910	0.173	475	0.179	7129	0.236
Pleasure driving	74	0.014	57	0.008	66	0.007	45	0.009	31	0.012	273	0.009
Other social or recreational	2224	0.413	2717	0.361	3244	0.346	1589	0.302	936	0.352	1071	0.355
Other	118	0.022	136	0.018	158	0.017	88	0.017	59	0.022	559	0.019
Home	7938	1.474	10943	1.454	14102	1.506	7079	1.345	3370	1.269	43432	1.438
Purpose category missing	784	0.146	1003	0.133	1227	0.131	1048	0.199	768	0.289	4830	0.160
Total	22,671	4.210	32,096	4.265	39,860	4.257	19,585	3.721	9,225	3.473	123,437	4.088
No. of travelers	5,385		7,526		9,364		5,264		2,656		30,195	
Mean No. of Trip Chains	1.474		1.454		1.506		1.345		1.269		1.438	
Mean No. of Trips per Chain	2.856		2.933		2.827		2.767		2.737		2.842	

Appendix Table 3.2: TRIP FREQUENCY AND TRIP RATE BY PURPOSE BY SEX

Purpose	Male		Female		Total	
	No.	Rate	No.	Rate	No.	Rate
Work	8398	0.456	7214	0.366	15612	0.409
Work-related business	964	0.052	608	0.031	1572	0.041
Shopping	6927	0.376	10464	0.531	17391	0.456
Other family or personal business	8942	0.485	12748	0.647	21690	0.569
School/church	4327	0.235	5076	0.258	9403	0.247
Doctor/dentist	338	0.018	680	0.035	1018	0.027
Vacation	68	0.004	88	0.004	156	0.004
Visit friends or relatives	3934	0.213	4776	0.242	8710	0.228
Pleasure driving	170	0.009	234	0.012	404	0.011
Other social or recreational	6728	0.365	6735	0.342	13463	0.353
Other	337	0.018	365	0.019	702	0.018
Home	25561	1.387	27899	1.416	53460	1.402
Purpose category missing	2690	0.146	3251	0.165	5941	0.156
Total	69,384	3.765	80,138	4.067	149,522	3.921
No. of travelers	18,429		19,706		38,135	
Mean No. of Trip Chains	1.387		1.416		1.402	
Mean No. of Trips per Chain	2.714		2.872		2.797	

Appendix Table 3.3: TRIP FREQUENCY AND TRIP RATE BY PURPOSE BY EMPLOYMENT

Purpose	Male		Female		Total	
	No.	Rate	No.	Rate	No.	Rate
Work	15294	0.689	320	0.020	15614	0.409
Work-related business	1470	0.066	102	0.006	1572	0.041
Shopping	10293	0.464	7099	0.445	17392	0.456
Other family or personal business	13542	0.610	8151	0.511	21693	0.569
School/church	2423	0.109	6982	0.438	9405	0.247
Doctor/dentist	486	0.022	532	0.033	1018	0.027
Vacation	95	0.004	61	0.004	156	0.004
Visit friends or relatives	4908	0.221	3803	0.238	8711	0.228
Pleasure driving	184	0.008	143	0.009	327	0.009
Other social or recreational	7599	0.342	5864	0.367	13463	0.353
Other	338	0.015	368	0.023	706	0.019
Home	32120	1.448	21351	1.338	53471	1.402
Purpose category missing	2793	0.126	3225	0.202	6018	0.158
Total	91,545	4.126	58,001	3.635	149,546	3.920
No. of travelers	22,188		15,958		38,146	
Mean No. of Trip Chains	1.448		1.338		1.402	
Mean No. of Trips per Chain	2.850		2.717		2.797	

Appendix Table 3.4: TRIP FREQUENCY AND TRIP RATE BY PURPOSE BY ROLE

Purpose	Male, Non-worker		Male, Worker		Female, Non-worker		Female, Worker		Total	
	No.	Rate	No.	Rate	No.	Rate	No.	Rate	No.	Rate
Work	137	0.021	8261	0.704	183	0.020	7031	0.673	15612	0.409
Work-related business	36	0.005	928	0.079	66	0.007	542	0.052	1572	0.041
Shopping	2394	0.358	4533	0.386	4705	0.508	5759	0.551	17391	0.456
Other family or personal business	2873	0.430	6069	0.517	5277	0.570	7471	0.715	21690	0.569
School/church	3202	0.479	1125	0.096	3778	0.408	1298	0.124	9403	0.247
Doctor/dentist	169	0.025	169	0.014	363	0.039	317	0.030	1018	0.027
Vacation	24	0.004	44	0.004	37	0.004	51	0.005	156	0.004
Visit friends or relatives	1483	0.222	2451	0.209	2319	0.250	2457	0.235	8710	0.228
Pleasure driving	67	0.010	103	0.009	76	0.008	81	0.008	327	0.009
Other social or recreational	2627	0.393	4101	0.349	3237	0.350	3498	0.335	13463	0.353
Other	155	0.023	182	0.016	209	0.023	156	0.015	702	0.018
Home	8879	1.328	16682	1.421	12464	1.346	15435	1.478	53460	1.402
Purpose category missing	1330	0.199	1360	0.116	1895	0.205	1433	0.137	6018	0.158
Total	23,376	3.495	46,008	3.919	34,609	3.737	45,529	4.359	149,522	3.921
No. of travelers	6,688		11,741		9,262		10,444		38,135	
Mean No. of Trip Chains	1.328		1.421		1.346		1.478		1.402	
Mean No. of Trips per Chain	2.633		2.758		2.777		2.950		2.797	

☆ U.S. GOVERNMENT PRINTING OFFICE:1995-387-554/35725

Recycled
Recycled

Publication No. FHWA-PL-95-033
HPM-40/2-95 (6.5M) E