1990 NPTS

Nationwide Personal Transportation Survey

Special Reports on Trip and Vehicle Attributes

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Summary of Travel Trends

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U.S. Department of Transportation
Federal Highway Administration

1990 NPTS Report Series

Special Reports on Trip and Vehicle Attributes

Based on Data from the
1990 Nationwide Personal Transportation Survey (NPTS)

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Foreword

This series of papers, using data from the Nationwide Personal Transportation Survey (NPTS), has forged new bridges between policy makers, planners, and the academic community. Too often, in the transportation field, we forget that people travel to accomplish activities important to their daily life—to travel to and from work, to take care of their family and themselves, and to enjoy recreational and social activities. NPTS has a specific focus on this personal travel, and allows researchers to examine a multitude of characteristics of persons, households, and vehicles relative to their daily travel.

These papers give us new insights into how people travel today, how this differs from past behavior, and understanding the complexity and variety of travel needs. We need better understanding of how our policy decisions may impact different groups and how our planning processes need to account for these variations.

In 1995, the next NPTS will be collected, adding to the data series started in 1969. This special series of papers has also contributed to improving the design and implementation of the NPTS.

Gloria J. Jeff
Associate Administrator for Policy
Federal Highway Administration

Introduction

The Nature of These Documents

This document is one of three volumes that have been produced as a set, containing topical subject papers from the Nationwide Personal Transportation Survey, NPTS. These volumes represent something of a departure from standard approaches to reporting the NPTS. Traditionally, the survey results have been reported in large volumes with an extensive series of tables, organized around important sections of the survey, or main categories of data, such as Vehicle-miles of travel, or work travel. While such volumes continue to be produced for the 1990 NPTS, they are being supplemented by a different approach as exemplified by these documents.

This new approach examines important emerging travel behavior trends, seeking to understand better key public policy issues on which the survey data can shed light. This approach is an outgrowth of a special study of the NPTS, entitled *Travel Behavior Issues in the 90's*, which provided an early look at the insights the NPTS could provide regarding significant policy-related topics. As a product of that study a series of additional topics were identified for further examination. Individual researchers were selected to intensively examine each subject and to prepare a paper presenting their findings. These papers have been compiled in the three volumes.

Value of This Approach

The goal of this approach is to advance understanding beyond that possible by traditional means. While the large volumes of summary tabulations produced from the survey are of great value, particularly in getting fundamental facts about travel on the record, they represent only one facet of the immense capabilities provided by the NPTS results. These supplemental, interpretive products support the role of the NPTS as an early warning system for emerging travel behavior trends, and as a mechanism for informing public policy officials.

The kind of presentation approach developed for these subjects recognizes the intended audience - primarily public officials, but also researchers, analysts and planners, as well as interested citizens. The extensive use of tables and graphics to make trends and patterns clearer is one attribute of the approach. But the fundamental characteristic that permeates these volumes is the synthesis of large masses of data from the survey into those that are central to understanding what demographic forces are affecting travel behavior.

Why These Subjects?

The subjects selected are something of a "hit parade" of major topics of interest coming from the NPTS. Topics have been selected that:

- are of substantial public interest,
- have bearing on current policy concerns,
- fill-in important questions about the direction and weight of current trends, and
- are sufficiently bounded so that a small individual study can make an incisive contribution to our understanding of travel phenomena.

As the purpose of this undertaking is to mine the rich resources of data from NPTS; it is the 1990 NPTS data set and its predecessor data sets from 1983, 1977, and 1969 that are the predominant, almost exclusive source of data for these studies. Where appropriate, researchers have used other data sets to extend or corrorborate the data.

Selected Studies

The twelve studies have been clustered into three groups based on their general subject matter. These are:

Demographic Special Reports

Chapter 1. An Assessment of the Potential Saturation in Men's Travel, Joel R. Rey, Steven E. Polzin, Ph.D., and Stacey G. Bricka

Chapter 2. Travel by Women, Sandra Rosenbloom, Ph.D.

Chapter 3. Travel by the Elderly, Sandra Rosenbloom, Ph.D.

Chapter 4. Multiworker Household Travel Demand, Siim Sööt, Ph.D., and Ashish Sen, Ph.D.

Chapter 5. Household Structure and Travel Behavior, Joan Al-Kazily, Ph.D., Carol Barnes, Ph.D., and Norman Coontz

Travel Mode Special Reports

Chapter 1. Travel by Households Without Vehicles, Charles Lave, Ph.D., and Richard Crepeau, Ph.D. Cand.

Chapter 2. Recent Nationwide Declines in Carpooling, Erik Ferguson, Ph.D.

Chapter 3. Non-Motorized Transportation, Debbie A. Niemeier, Ph.D. Cand., and G. Scott Rutherford, Ph.D.

Special Reports on Trip and Vehicle Attributes

Chapter 1. Understanding Trip Chaining, James Strathman, Ph.D., and Kenneth Dueker, Ph.D.

Chapter 2. Geographic Factors Explaining Work Trip Length Changes, Peter Gordon, Ph.D., and Harry Richardson, Ph.D.

Chapter 3. The Demography of the U.S. Vehicle Fleet, Alan Pisarski

Chapter 4. Time-of-Day Characteristics of Travel, Ryuichi Kitamura, Ph.D.

There are many other NPTS products already available or underway that go well beyond these subject studies. They are listed on the inside cover of this document.

Broad Findings

It is not feasible to summarize the individual findings of these twelve studies in a brief fashion. Twelve studies cover a broad range of subjects; all address different facets of travel characteristics or travel behavior. However, there are major themes that emerge from the materials. These themes were developed in a two day conference held in Arlington, Va. on April 20 and 21, 1994, in which the researchers presented the findings of their work and invited panelists and other conference participants to discuss the implications of the findings. The themes arose as part of the presentations of the researchers and from the separate workshop discussions that followed.

One of the themes, which has to be expressed with some care, is that researchers have discovered, or re-discovered, how complex is travel behavior and its demographic determinants. It may sound overly simplistic, or even selfserving, to state that travel behavior is increasingly complex but it does appear to be the case. There are several interrelated factors contributing to this trend, but the dominant one is the changing role of women.

This phenomenon is expressed, of course, in the paper addressing the travel characteristics of women, but it also permeates the content of the papers on multi-worker households, household structure, and the topic of trip chaining. The topic of suburbanization and work trip lengths is also affected.

Perhaps the major theme that emerges from the papers is that of issues of equity - equity for women, low income groups, racial and ethnic groups, and the aged. Almost all of the papers make a contribution to this topic, expanding and revealing some of the elements of the key issues surrounding the subject. Even the topic of the aging of the vehicle fleet contains elements of equity concern.

The final major theme links to topics of relevance to environmental concerns. One of these, of course, is the study of the aging of the vehicle fleet. But this, by far, is not the only material of great relevance. Other pertinent papers include the studies of trip time patterns, multi-worker households, walking patterns, geographic factors in trip length, the potential saturation of male travel, and perhaps most significantly, trip chaining characteristics.

There are other themes as well, many of them sub-themes derivative of the major themes. For the most part, the subthemes relate to more technical and organizational aspects of current transportation planning processes. There are three important elements among these technical themes.

- The federal regulatory process, at DOT and other agencies needs to take these patterns and trends into account.
- The state and metropolitan planning processes need to better understand these behavioral patterns and their implications for local travel needs.
- The relationships identified in these studies need to be incorporated better in the current modeling and forecasting systems in use at the state and metropolitan levels.

A final theme that arose again and again concerned the need for better mechanisms to inform the policy process of the character of travel behavior and its changing implications for public policy.

The reader will want to be alert to these themes and to the many others that permeate these reports which the reader may discover.

Alan E. Pisarski

Authors' Biographies

Kenneth Dueker, Ph.D., is the Director of the Center for Urban Studies at Portland State University. Dr. Dueker chairs the TRB Subcommittee on Geographic Information Systems in Transportation. **James Strathman, Ph.D.,** is the Assistant Director of the Center for Urban Studies at Portland State University. These investigators' 1992 analysis of trip chaining in the Portland, Oregon metropolitan area—supported by the U.S. DOT University Transportation Centers program—identified key life cycle, personal, and traffic elements associated with the organization of household travel. The timely Portland analysis demonstrated the relevance of the trip chaining framework in evaluating the potential or consequences of alternative congestion management strategies, as well as possible trade-offs between congestion management and VMT control.

Peter Gordon, Ph.D., and **Harry Richardson, Ph.D.,** of the School of Urban and Regional Planning at the University of Southern California are two of the most widely respected researchers using NPTS data. Specifically, they are the most widely quoted and acknowledged investigators of work trip lengths and commuting patterns. Their papers, "Congestion, Changing Metropolitan Structure, and City Size in the United States," and "The Spatial Mismatch Hypothesis: Some New Evidence," published in 1989, have generated animated discussions in the planning community and have led to further explorations of urban development patterns and travel behavior.

Mr. Alan Pisarski, has been actively involved with national transportation policy and related data for the past 20 years. He has served as a consultant to the U.S. Department of Transportation on Secretary Skinner's national transportation policy and acted as a technical advisor on the preparation of a four-part series on transportation for public television. He is the author of numerous publications, including the widely distributed report, "Commuting in America," which traces national commuting trends over the past 20 years. Most recently he has authored two publications, "New Perspectives in Commuting" and "Travel Behavior Issues in the 90's."

Ryuichi Kitamura, Ph.D., is Professor of Civil Engineering at Kyoto University and the University of California, Davis. Dr. Kitamura's work has advanced the state-of-the-art of travel behavior research, and is a leader in activity-based travel demand models. Dr. Kitamura serves as the chair of the Committee of Traveler Behavior and Values, and served as the founding chair of the Subcommittee on Activity and Travel Pattern Analysis, both for Transportation Research Board.

Special Reports on Trip and Vehicle Attributes

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Understanding Trip Chaining

James G. Strathman, Ph.D., and Kenneth J. Dueker, Ph.D.

Acknowledgments

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Understanding Trip Chaining

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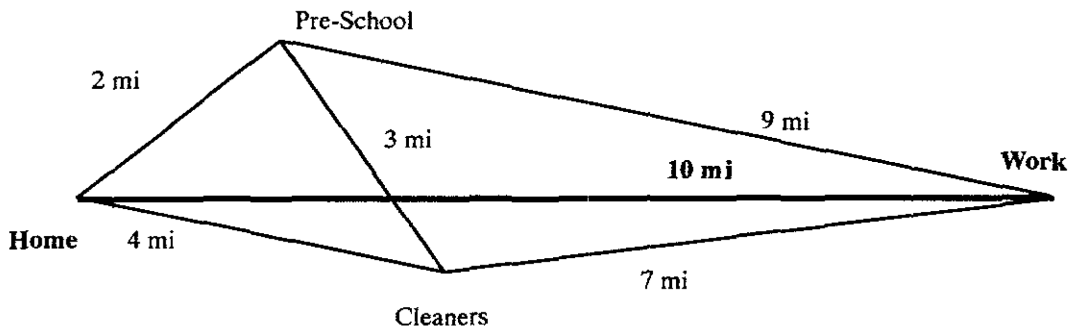
Introduction and Overview

Person trips are a basic unit of measurement in the Nationwide Personal Transportation Survey (NPTS). The "trip" element in this measure is defined as "one-way travel from one place (address) to another by any means of transportation," while the "person" element identifies the subject. In many instances, person trips are a valid indicator of travel. Sometimes, however, they are not. A hypothetical example offers the most convenient way to illustrate how trips are coded in the NPTS and the problems that arise when these trips are combined ("chained") into multiple stop journeys. Figure 1 presents a simple two dimensional map of a person's commuting network. The network is anchored at one end by the worker's home and at the other end by his place of work. Two stops that are sometimes made between home and work are identified. Distances between the various locations on the network are also given.

Figure 1: HYPOTHETICAL COMMUTING ROUTES



The worker's commuting itinerary in a typical week is as follows:

	AM Commute Stops	*PM Commute Stops*
Monday	Pre-School	Pre-School
Tuesday	None	None
Wednesday	Pre-School; Cleaners	Pre-School
Thursday	None	Cleaners
Friday	None	Pre-School

As coded in the NPTS, the worker's commute contains both work and non-work trips. For example, the Monday AM commute consists of a two mile *family and personal business* trip to the pre-school, followed by a nine mile *to work* trip. The Monday PM return commute begins with a nine mile *family and personal business* trip to the preschool, followed by a two mile *from work* trip home.

The non-work trips in this example are treated as independent in the NPTS, which in the above illustration clearly complicates attempts to analyze the work commute. For example, if we were to ask how long this person's commute is based on his coded work trips, the answer would be "it depends." Coded work trip distances vary both by day and direction, as shown in Table 1. As the table indicates, AM work trips average 9.2 miles, while PM work trips average 4.0. Moreover, the daily one-way average ranges from 4.5 (Wednesday) to 10 miles (Tuesday). The overall average work trip distance of 6.6 miles is 34 percent *less* than the "shortest path" commuting route between the person's residence and work place. What this example reveals is that trip purpose as coded in the NPTS can cause problems in analyzing total commute travel. Also, the deviations of work trip and commuting distances in this example are all in the same direction.

Table 1: WORK TRIP DISTANCES FOR A HYPOTHETICAL COMMUTER (MILES)

Day	AM Commute	PM Commute	AM/PM Average
Monday	9	2	5.5
Tuesday	10	10	10.0
Wednesday	7	2	4.5
Thursday	10	4	7.0
Friday	10	2	6.0
Daily Average	9.2	4.0	6.6

This indicates that when the commute involves stops between home and work, coded work trip distances in the NPTS will be shorter than the actual distances between these two points.

An exact portrayal of the journeys in this example can be obtained by linking the trips in the commute, forming *trip chains*. When a journey is comprised of a single non-home destination, the trip chain is termed "simple" in the sense that it is equivalent to the coded trip. Alternatively, "complex" trip chains represent journeys involving multiple non-home destinations. It may also be important to know, as in the commuting example, whether the complexity of a journey exists in the outbound or homeward portion. Below, we again portray the hypothetical weekly commuting itinerary, but this time we depict each commute as its trips would be coded in the NPTS, and (in parentheses) as it would be characterized in trip chaining terminology.

	AM Commute	*PM Commute*
Monday	Personal Business; Work ("Complex to Work")	Personal Business; Work ("Complex from Work")
Tuesday	Work ("Simple Work")	Work ("Simple Work")
Wednesday	Personal Bus.; Personal Bus.; Work ("Complex to Work")	Personal Business; Work ("Complex from Work")
Thursday	Work ("Simple Work")	Personal Business; Work ("Complex from Work")
Friday	Work ("Simple Work")	Personal Business; Work ("Complex from Work")

The trip chain framework permits a less ambiguous response to the commuting distance question. For example, if one is interested in commuting distance to represent the spatial separation of home and the work place, only work trips in the NPTS comprising "simple work" chains should be employed.

Analyzing trip chaining activity may lead to better understanding of travel behavior and provide a more appropriate framework for examining some transportation policy issues. For example, it has been observed that non-work trip-making has been growing rapidly during peak commuting times (1). Such growth would seem surprising in a context of unlinked trips because one would not expect people to schedule so-called "discretionary" travel during the most congested periods. Alternatively, if peak non-work trips are frequently linked to commutes, then a basis for the apparently illogical travel behavior can be established. For example, it has been observed that single person and multiple adult worker households have a greater tendency to combine work and non-work trips than do commuters from family households in which only one adult is employed (2). Since the former household types have been growing in number more rapidly than the latter during the past twenty-five years, we can infer that household composition changes have contributed to the growth of non-work travel during peak commuting hours, and observed increases in the complexity of trip chains over time (3).

Moreover, the 1990 NPTS reveals the predominant reliance on automobiles for the journey to work (4). Since the automobile provides enhanced flexibility in organizing daily activities, non-work activities can be more easily coordinated with the work commute. Thus, the shift of commuters from public transit to automobiles contributes to traffic congestion directly (in the growth of work-based vehicle trips) and indirectly (in the growth of non-work vehicle trips made in conjunction with the commute).

What are the policy implications of the links between work and non-work trips, and trip chaining more generally? First, the non-work trips in the commuting example are probably not as discretionary as one might think, and they may well constrain the scheduling of commutes. Experience indicates a fairly strong resistance to rescheduling work periods (5, 6). Workers' reluctance to re-schedule their commutes is understandable considering that non-work obligations often must be satisfied in these journeys.

Second, single occupant vehicle commuting coupled with changing household structure have stimulated peak period non-work travel, exacerbating congestion. Household demographics fall outside the transportation policy arena, but vehicle occupancy clearly can be influenced, with potentially important consequences. For example, an increase in vehicle occupancy or a switch to transit resulting from congestion tolls or parking price increases would, holding the number of person trips constant, reduce the number of vehicle trips during peak commuting periods. What is not recognized in the "independent" trip perspective is that an additional shifting of non-work trips linked to commuting is likely to occur when the convenience of SOV travel is given up.

Shifting non-work elements of the commute to off-peak periods contributes in principle to more efficient use of transportation infrastructure. However, it may also stimulate some undesirable environmental side effects. It has been estimated that non-work trips made independent of the work commute are 10 to 20 percent longer, and about two-thirds of these journeys involve trips to a single destination (7). Thus, if trip chaining in conjunction with the journey to work was discouraged, vehicle emissions and the proportion of "cold starts" would probably increase.

For at least the past 15 years transportation researchers have stressed the importance of the work commute as an organizing element of household travel. Empirical studies of trip chaining support this view, indicating that 10 to 20 percent of all non-work trips are linked to the work commute. Studies indicate that activities other than employment also provide an organizational focus for multi-trip journeys (8, 9, 10).

Trip chaining studies have usually relied on travel data from specific metropolitan areas. The problems of generalizing the findings of local studies are well known. Most researchers in this field would acknowledge that without analysis of trip chaining at the national level, our understanding of travel behavior suffers and our ability to devise wise policies is more limited.

In the following sections we define the trip chaining typology employed in the report, and describe the procedure used to generate trip chains from person trips in the NPTS. We then present trip chaining patterns distinguished by travel purpose, geographic, socio-economic and demographic factors. We also estimate the bias associated with equating work trips with work commutes. The report concludes with a discussion of research needs and opportunities.

Derivation of Trip Chains

The trip chain typology employed in this report is based on person trips reported in the day trip file of the 1990 NPTS, and identifies two general travel purposes—work and non-work. Second, the typology distinguishes between simple journeys, involving a person trip from home to a given destination and then returning home, and complex journeys, involving a sequence of more than two person trips that begins and ends at home. The greatest amount of detail involves distinguishing among four types of complex work chains, based on the point(s) in the commute where non-work trips might occur: (1) on the way to work; (2) on the return from work; (3) both on the way to and the return from work; and (4) during the work day. The typology is illustrated in Figure 2.

Figure 2: TRIP CHAIN TYPOLOGY

Trip Chain Type	Configuration*
Simple Work	H - W { - W - } - H
Complex To Work	H - NW { - NW/W - } - W - H
Complex From Work	H - W { - NW/W - } - NW - H
Complex To & From Work	H - NW { - NW/W - } - W - { - NW/W - } - NW - H
Complex At Work	H - W { - NW/W - } - NW - { - NW/W - } - W - H
Simple Non-Work	H - NW - H
Complex Non-Work	H - NW { - NW - } - H

*H = Home; W = Work; NW = Non-Work. The bracketed terms represent additional trips which may be present in the chain.

Some of the subjects to be discussed in the following sections of the report call for a more detailed breakdown of the trip chaining types than others. In these instances we will employ the full breakdown of the seven trip chaining types listed in Figure 2. In other cases less detail is necessary, and there we aggregate the four complex commuting chain types. Finally, in selected instances we focus exclusively on the five work chain types. The seven category breakdown will be referred to as the **Main** typology. The **Grouped** typology will refer to the four category set including simple/complex work/non-work chains, and the **Commute** typology will refer to the five work-related chain categories in Figure 2.

It was not possible to link all the trips reported in the day trip file into the various trip chains. Trips contained in sequences that did not begin and end at home were not included. These sequences represent individuals who typically either began or ended their travel day away from home. Also, trips in "broken" chains, in which a given destination address was not coded as the subsequent origin address, were not included. Chains representing over 93% of the nearly 250 billion person trips in the 1990 NPTS were constructed (see Table 2).

Table 2: DISTRIBUTION OF TRIP CHAINS AND TRIPS

	Trip Chains (Millions)	Trips (Millions)
Valid Trip Chains	89,262	232,317
Invalid Trip Chains	8,333	17,245
Total	97,595	249,562

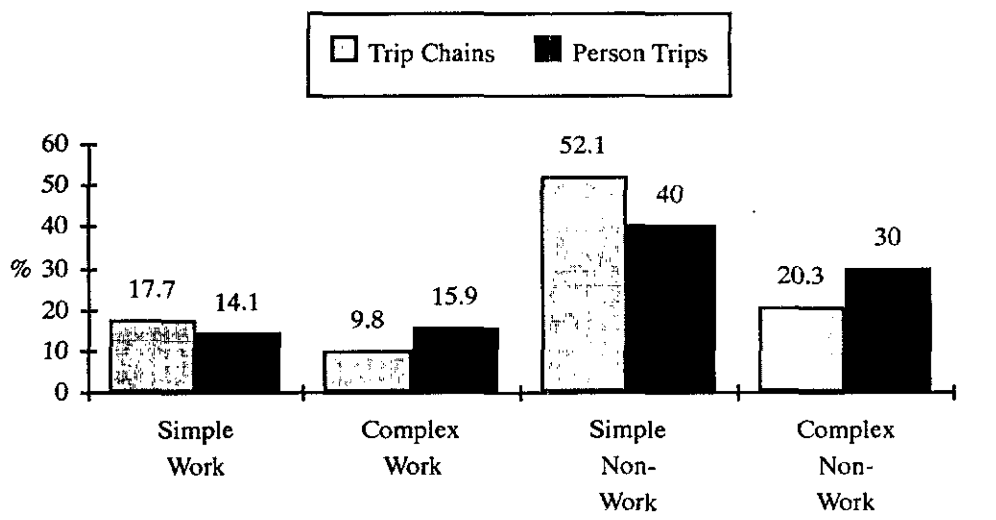
Contributing Elements

In this section we examine trip chaining patterns through a number of cross tabulations involving trip chaining, household and urban characteristics, mode of travel and commuting. The approach is necessarily discursive given the number of topics covered, and in that we do not seek to determine whether the trip chaining patterns are significant statistically.

Distribution of Trip Chains and Person Trips

Trip chains related to work commuting account for 27.5% of all Grouped chains and contain 30% of all person trips (see Figure 3). By comparison, the *Summary of Travel Trends* (11) reports that work travel accounted for 21.6% of the person trips in the 1990 NPTS. The journey to work is thus a more important organizational element of household travel activity than trip-based statistics tend to indicate. Work commutes are also more likely to be comprised of multiple trips than are non-work journeys: 35.6% of all work related trip chains are complex, as compared to 28.0% of non-work chains.

Figure 3: DISTRIBUTION OF GROUPED TRIP CHAINS AND PERSON TRIPS (PERCENT)



A more detailed portrayal of the work commute is provided in Table 3. The likelihood of a commute containing non-work trips in the *to home* portion only is nearly five times the likelihood of a commute containing non-work trips in the *to work* portion only. Moreover, commutes which are complex only in the *to home* portion account for more chains (6.4%) and person trips (9.7%) than the other three complex commuting alternatives combined. The number of trips per chain is reported in the right-hand column of Table 3. Simple commutes, for example, average a trip *to work*, a trip *to home* and, in one of ten instances, a work related trip. Complex to Work, Complex from Work and Complex Non-Work chains contain nearly two more trips than a simple chain. Chains that are complex both to and from work contain the greatest number of trips. Finally, although chains which are complex during the work day comprise a fairly small percentage of all trip chains (0.6%), they average three trips in addition to the trips to and from work.

Table 4 provides a more detailed breakdown of trip chaining activity within the Main typology with respect to non-work trip purpose. Given non-work activities are more likely to be contained in some types

Table 3: DISTRIBUTION OF MAIN TRIP CHAIN TYPES AND PERSON TRIPS (MILLIONS)

	Trip Chain Type							
	Work					Non-Work		
Trip Category	Simple	Complex To	Complex From	Complex To & From	Complex At	Simple	Complex	Total
Trip Chains	15,834	1,184	5,724	1,354	562	46,479	18,126	89,262
Percent	17.7	1.3	6.4	1.5	0.6	52.1	20.3	100.0
Person Trips	32,856	4,337	22,474	7,240	2,792	92,962	69,656	232,317
Percent	14.1	1.9	9.7	3.1	1.2	40.0	30.0	100.0
Trips Per Chain	2.1	3.7	3.9	5.3	5.0	2.0	3.8	2.6

Table 4: TRIPS PER CHAIN BY PURPOSE AND MAIN TRIP CHAIN TYPE

	Trip Chain Type						
	Work					Non-Work	
Trip Category	Simple	Complex To	Complex From	Complex To & From	Complex At	Simple	Complex
Work	2.00	2.04	2.05	1.98	2.08	0.00	0.00
Work-Related Business	.08	.15	.09	.17	.67	0.00	0.00
Shopping	0.00	.23	.54	.62	.41	.48	.99
Other Family/ Personal Bus.	0.00	.77	.79	2.06	1.48	.40	1.20
School/Church	0.00	.17	.04	.12	.02	.44	.31
Doctor/Dentist	0.00	.01	.04	.03	.08	.02	.05
Vacation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Visit Friends/Relatives	0.00	.10	.15	.16	.05	.24	.49
Pleasure Driving	0.00	0.00	0.00	0.00	0.00	.02	.02
Other Social/ Recreational	0.00	.18	.21	.19	.18	.38	.73
Other	0.00	.01	.01	.02	.02	.02	.04
Trips Per Chain	2.08	3.66	3.92	5.35	4.98	2.00	3.83

of trip chains than others. Shopping trips predominate in complex non-work chains and are relatively infrequent in complex *to work* chains. Trips whose purpose is other family/personal business are most heavily represented in chains that are complex both to and from work. School and church related trips are most heavily represented in simple non-work chains, and visits to the doctor or dentist are most often made during the work day. Visits to friends and relatives and other social and recreational trips are most likely to be contained in complex non-work chains.

Trip Chaining and Gender

In both work and non-work travel women exhibit a greater tendency to organize their trips into chains (see Figure 4 and Table 5). Within the Grouped typology the likelihood that a woman's commute will be complex is 37% greater than a man's (.42 for women versus .306 for men). For non-work travel, the likelihood of a complex journey for women (.299) is 15% greater than the likelihood for men.

Figure 4: PERCENTAGE OF WORK AND NON-WORK TRIP CHAINS FOR MEN AND WOMEN THAT ARE COMPLEX

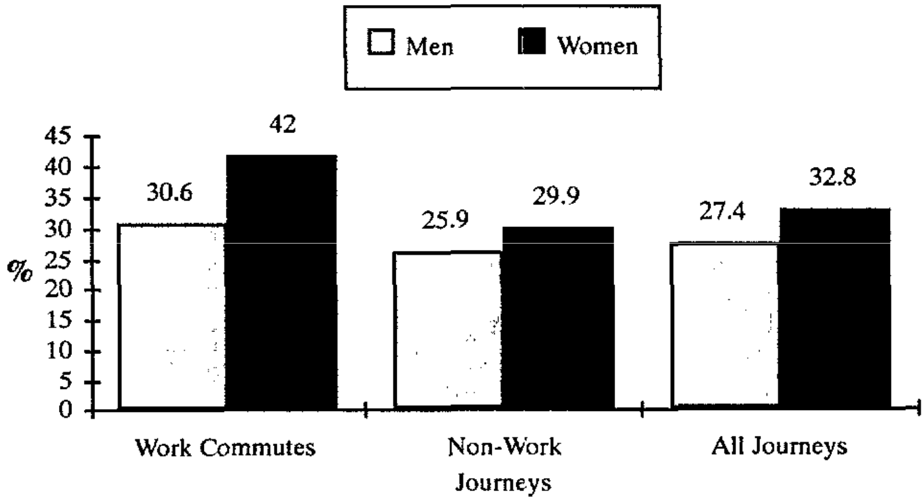


Table 5: GROUPED TRIP CHAINS OF MEN AND WOMEN (MILLIONS)

	Trip Chain Type				
Gender	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
Men	9,305	4,095	21,899	7,663	42,951
Women	6,527	4,729	24,578	10,462	46,295
N.A.*	2	0	12	2	16
Total	15,834	8,824	46,489	18,127	89,262

*Not Ascertained/Refused.

Table 6: DISTRIBUTION OF GROUPED TRIP CHAINS BY HOUSEHOLD INCOME (PERCENT)

	Trip Chain Type				
Income Category	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
L. T. $5,000	8.5%	4.2%	61.4%	25.9%	100.0%
$5,000-9,999	12.1	5.4	61.3	21.2	100.0
$10,000-14,999	15.4	7.4	55.6	21.6	100.0
$15,000-19,999	17.1	9.4	53.0	20.5	100.0
$20,000-24,999	19.0	10.1	50.7	20.2	100.0
$25,000-29,999	17.1	9.4	52.7	20.8	100.0
$30,000-34,999	17.4	10.8	50.8	21.0	100.0
$35,000-39,999	18.5	11.5	50.0	20.0	100.0
$40,000-44,999	17.9	11.3	49.0	21.8	100.0
$45,000-49,999	18.4	10.9	50.0	20.7	100.0
$50,000-54,999	18.5	12.4	50.0	19.1	100.0
$55,000-59,999	18.2	11.8	50.9	19.2	100.0
$60,000-64,999	18.0	12.8	47.7	21.5	100.0
$65,000-69,999	18.0	13.2	49.2	19.6	100.0
$70,000-74,999	18.1	13.2	46.2	22.6	100.0
$75,000-79,999	15.9	15.0	49.8	19.2	100.0
$80,000+	18.9	11.1	47.8	22.2	100.0

Trip Chaining and Income

The share of simple non-work journeys declines as household income increases. Over 60% of the Grouped trip chains of households with incomes less than $10,000 are simple non-work, as compared to less than 50% for households with incomes over $30,000 (see Table 6). Higher income households exhibit a greater tendency to combine work and non-work trips. Nevertheless, the share of simple work chains is greater for higher income households.

Trip Chaining and Time of Travel

Based on the Grouped typology, Figure 5 shows that complex chains are more likely than simple chains to occur during the peak period. For commute chains, 87 percent of complex chains occur in the peak period compared to 77 percent of simple chains. Complex chains may be more peak oriented due to a need to meet scheduled stops, or possibly because complex chains have longer durations.

Figure 5: TIME OF TRAVEL: GROUPED TRIP CHAINS (PERCENT)

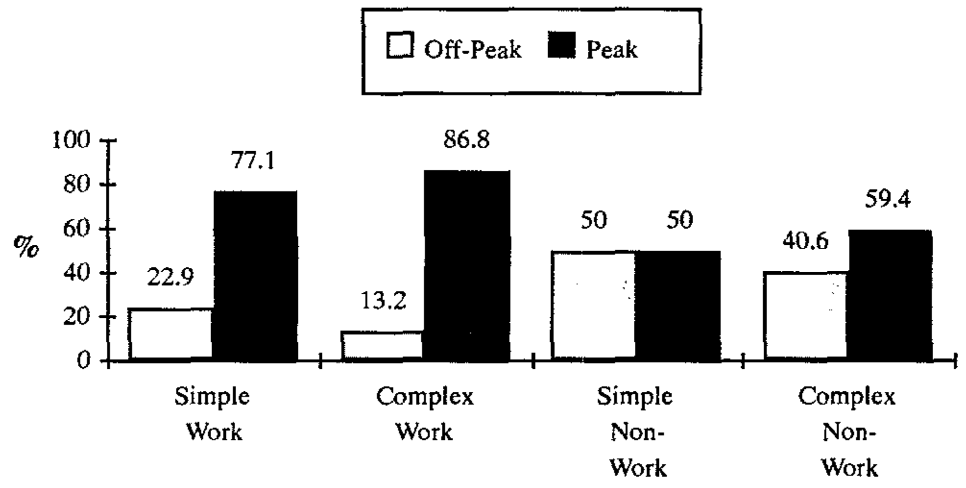
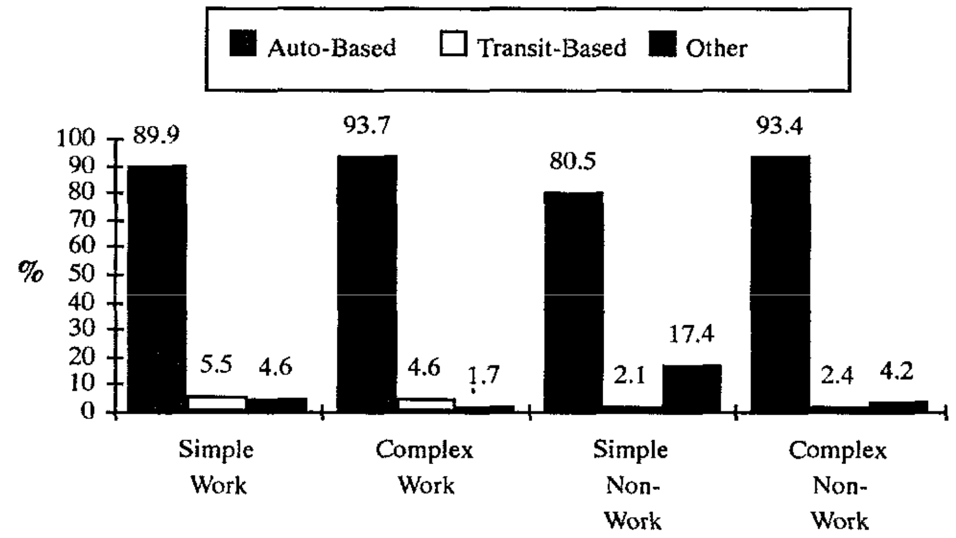


Figure 6: GROUPED TRIP CHAIN DISTRIBUTION BY PRINCIPAL MODE OF TRAVEL (PERCENT)



Trip Chaining and Travel Mode

Based on the Grouped typology, Figure 6 shows that complex trip chains tend to be more auto oriented. The cause of this shift is not unilaterally evident, however. Is it the choice of the auto mode that makes the journey more likely to be complex, or are complex travel activity itineraries contributing to a higher likelihood that a person will choose the automobile?

Table 7: GROUPED TRIP CHAIN DISTRIBUTION BY TIME OF TRAVEL (MILLIONS)

	Trip Chain Type				
Travel Period	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
Peak*	12,200	7,662	23,229	10,767	53,858
Off-Peak	3,633	1,160	23,250	7,360	35,404
Total	15,833	8,822	46,479	18,127	89,262

* The peak periods are 6:30 to 9:00 AM and 3:30 to 6:00 PM.

Table 8: DISTRIBUTION OF GROUPED TRIP CHAINS BY TRAVEL MODE (MILLIONS)

	Trip Chain Type				
Mode	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
Auto Only	14,113	7,801	36,593	15,730	74,237
Transit Only	628	45	710	47	1,430
Auto/Transit	133	112	108	101	453
Auto/Other	128	470	838	1,192	2,628
Transit/Other	73	175	102	236	586
Auto/Transit/Other	26	73	4	52	155
Other	728	149	8,102	769	9,749
N.A.*	4	0	20	0	24
Total	15,833	8,825	46,477	18,127	89,262

* Not Ascertained

Table 9: DISTRIBUTION OF GROUPED TRIP CHAINS BY LOCATION OF RESIDENCE (PERCENT)

	Trip Chain Type				
Metropolitan Status	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
MSA Central City	17.9	9.8	52.3	20.1	100.0
MSA Suburban	17.8	10.5	51.0	20.8	100.0
Non-Metropolitan	17.5	8.8	53.8	19.9	100.0

Trip Chaining and Urban Status

The distribution of Grouped trip chain types is not strongly related to residential location status, broadly defined. Metropolitan suburban residents have a somewhat smaller share of simple non-work chains and a slightly larger share of complex work chains than do central city and non-metropolitan residents. Non-metropolitan residents have the largest percentage of simple non-work chains (see Table 9).

The percentage of simple work chains becomes progressively larger as urban population increases (see Table 10). This upward trend is offset by declines in the shares of both simple and complex non-work chains. Hence, the share of work based trip chains is positively related to metropolitan size.

Table 10: DISTRIBUTION OF GROUPED TRIP CHAINS BY METROPOLITAN SIZE (PERCENT)

	Trip Chain Type				
MSA/CMSA Size	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
L.T. 250,000	15.7%	10.1%	52.7%	21.5%	100.0%
250,000-499,999	16.5	10.4	51.7	21.4	100.0
500,000-999,999	17.5	10.3	51.6	20.6	100.0
1,000,000-2,999,999	18.5	9.7	50.7	21.1	100.0
G.T. 3,000,000	18.5	10.4	51.7	19.3	100.0

Trip Chaining and Household Size

Single person households have the greatest likelihood of forming complex trip chains (see Figure 7). Based on the Grouped typology, the share of complex work chains declines and the share of simple non-work chains grows with increases in the number of persons per household (see Table 11).

Figure 7: PERCENTAGE OF GROUPED TRIP CHAINS THAT ARE COMPLEX, BY HOUSEHOLD SIZE

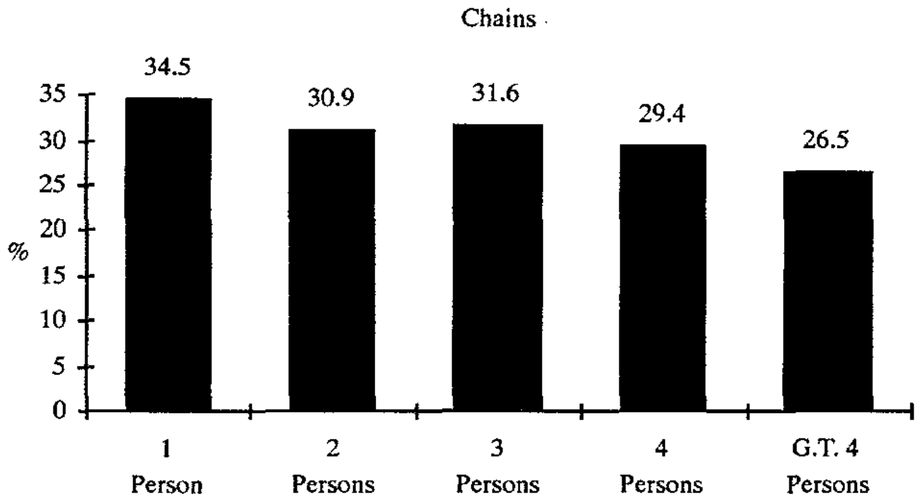


Table 11: DISTRIBUTION OF GROUPED TRIP CHAINS BY SIZE OF HOUSEHOLD (PERCENT)

	Trip Chain Type				
Household Size	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
1 Person	15.5%	12.1%	50.0%	22.4%	100.0%
2 Persons	20.1	10.7	48.9	20.2	100.0
3 Persons	20.2	11.4	48.2	20.2	100.0
4 Persons	16.9	9.0	53.6	20.4	100.0
G. T. 4 Persons	14.4	7.3	59.0	19.2	100.0

Trip Chaining and Life Cycle

Trip chaining patterns vary considerably with respect to household life cycle stage (see Table 12). Based on the Grouped typology, single and multiple adult households—the first two life cycle categories in Table 12—account for the largest percentage of work related chains (38.6% of all chains for households comprised of two or more adults, and 35.5% for single adult households), while the percentage of trip chains linked to the commute is smallest for single adults with children age 15 and less (16.8% for single adults with children age 0-5, and 17.6% for households with children age 6-15).

For non-work travel the relative likelihood of complex trip chaining is greatest for single adults with children age 16-21 and single adults (33.5% and 31.8% of these respective group's non-work chains are complex), while the relative likelihood of complex chaining is least for households comprised of two or more adults with children age 6-15 (24.5%) and households with two or more retired adults (25.2%).

Table 12: DISTRIBUTION OF GROUPED TRIP CHAINS BY HOUSEHOLD LIFE CYCLE STAGE (PERCENT)

	Trip Chain Type				
Life Cycle Category	Simple Work	Complex Work	Simple Non-Work	Complex Non-Work	Total
1 Adult	20.0%	15.5%	44.0%	20.5%	100.0%
2+ Adults	25.9	12.7	42.6	18.8	100.0
1 Adult; Ch. 0-5	7.9	8.9	57.6	25.6	100.0
2+ Adults; Ch. 0-5	16.4	10.6	52.0	21.0	100.0
1 Adult; Ch. 6-15	9.4	8.2	58.5	23.9	100.0
2+ Adults; Ch. 6-15	14.8	7.9	58.3	18.9	100.0
1 Adult; Ch. 16-21	16.7	8.6	50.0	25.2	100.0
2+ Adults; Ch. 16-21	24.0	10.8	45.9	19.4	100.0
1 Retired Adult	1.3	.6	70.1	28.0	100.0
2+ Retired Adults	7.9	3.2	66.6	22.4	100.0
Not Ascertained	22.3	9.1	48.2	20.4	100.0

Commuting Chains and Urban Area Size

Cross tabulation of duration, distance, and speed of work trips contained in the various types of commute chains are reported in Table 13. Note that the figures in the table are for work trips and do not reflect non-work trips that are present in complex commute chains. Focusing on work trips in this way reveals more clearly how the presence of non-work trips in the commute affects work trip characteristics, as coded in the NPTS.

Table 13 shows that work trip distance and duration increase and speed decreases with respect to urban area size. Simple commute chains follow this pattern more than do complex commute chains. For simple commute chains, work trip length and duration in metropolitan areas with more than three million residents are 27 and 49 percent greater than in metropolitan areas with less than 250,000 residents, while average speed is about 15 percent lower. Work trip lengths in non-metropolitan areas are generally greater than lengths in all but the largest metropolitan areas. Work trips in simple commute chains are 26% slower in the largest metropolitan areas than in non-metropolitan areas (29.4 versus 39.5 mph).

Table 13: COMMUTE TRIP CHAINS, BY METROPOLITAN SIZE*

	Trip Chain Type					
MSA/CMSA Size	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Row Av.
I. Distance (Miles)						
L. T. 250,000	9.5	11.7	8.3	8.0	—	9.2
250,000-499,999	9.5	7.6	10.1	9.5	—	9.6
500,000-999,999	11.3	7.9	10.2	12.9	9.8	10.9
1,000,000-2,999,999	10.8	9.3	11.3	9.6	9.0	10.8
G. T. 3,000,000	12.1	12.1	12.5	9.9	14.2	12.2
Non-Metropolitan	11.7	10.8	10.9	9.9	8.6	11.3
II. Duration (Min.)						
L. T. 250,000	16.6	19.5	14.9	14.4	—	16.2
250,000-499,999	17.0	14.2	17.0	17.0	—	16.8
500,000-999,999	19.8	16.5	18.0	19.9	17.8	19.2
1,000,000-2,999,999	20.8	19.0	20.0	18.0	16.9	20.3
G. T. 3,000,000	24.8	23.8	24.6	19.0	25.8	24.4
Non-Metropolitan	17.8	15.6	17.3	15.5	13.2	17.4
III. Speed (MPH)						
L. T. 250,000	34.5	36.1	33.3	33.6	—	34.3
250,000-499,999	33.5	32.3	35.7	33.4	—	34.1
500,000-999,999	34.3	28.6	33.9	38.7	33.2	34.3
1,000,000-2,999,999	31.2	29.2	34.0	32.2	31.9	31.8
G. T. 3,000,000	29.4	30.5	30.5	31.3	33.1	29.9
Non-Metropolitan	39.5	41.3	37.8	38.4	39.1	39.1

* Blank cells represent fewer than 30 observations, and their values are thus not reported.

The relative importance of simple commute chains generally increases with metropolitan area size (see Table 14). The trend in increasing simplicity does not hold for metropolitan areas with more than three million residents, due to the greater percentage of complex commutes on the return leg in that size category. Non-metropolitan areas had the largest percentage of simple commutes.

Table 14: DISTRIBUTION OF COMMUTE TRIP CHAINS BY METROPOLITAN SIZE (PERCENT)

	Trip Chain Type					
MSA/CMSA Size	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Total
L. T. 250,000	61.7%	5.2%	25.3%	5.0%	2.8%	100.0%
250,000-499,999	61.6	4.2	26.0	6.0	2.2	100.0
500,000-999,999	62.2	5.0	23.8	6.0	3.0	100.0
1,000,000-2,999,999	65.0	4.8	23.0	4.9	2.4	100.0
G. T. 3,000,000	63.5	5.1	25.7	3.8	1.9	100.0
Non-Metropolitan	66.2	4.3	22.2	5.2	2.1	100.0

Commuting Chains and Life Cycle

Cross tabulation of work trip distance, duration and speed by commute chain type and life cycle category shows that work trip distances and speeds are generally lower for single adults with pre-school and school age children than for their two adult household counterparts (see Table 15). This distinction was not evident for households with children age 16-21.

Table 16 decomposes household commuting according to life cycle category and commute chain type. Single adults with young children are the most likely to have complex commute chains both to and from work (32% of single adult households with children 0-5 years of age, and 12.5% of single adult households with children 6-15 years of age as compared to 4.9% for all complex commute chains for all households). Similarly, single adult households with pre-school and adolescent children exhibit the lowest rate of simple work commute chaining (44.8% and 49.5% as compared to 64.0% for all simple commute chains).

Table 15: COMMUTE TRIP CHAINS, BY LIFE CYCLE CATEGORY*

Life Cycle Category	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Row Av.
			I. Distance (Miles)			
1 Adult	9.5	12.8	10.8	9.9	—	10.1
2+ Adults	11.4	10.5	11.5	11.4	13.3	11.4
1 Adult; Ch. 0-5	8.7	—	—	6.7	—	8.0
2+ Adults; Ch. 0-5	13.1	10.2	12.7	10.1	12.5	12.5
1 Adult; Ch. 6-15	10.1	—	10.0	10.6	—	10.1
2+ Adults; Ch. 6-15	12.0	10.6	11.4	8.8	9.0	11.5
1 Adult; Ch. 16-21	12.1	—	—	—	—	11.4
2+ Adults; Ch. 16-21	11.3	13.0	10.7	—	—	11.3
1 Retired Adult	—	—	—	—	—	—
2+ Retired Adults	9.7	—	8.9	—	—	9.8
Not Ascertained	11.5	—	—	—	—	9.8
Column Average	11.6	10.9	11.4	9.9	11.1	11.4
			II. Duration (Min.)			
1 Adult	17.3	19.5	19.0	16.3	—	17.9
2+ Adults	19.9	19.0	19.1	18.3	21.3	19.7
1 Adult; Ch. 0-5	15.1	—	—	15.3	—	15.3
2+ Adults; Ch. 0-5	21.3	19.0	20.7	17.4	18.8	20.5
1 Adult; Ch. 6-15	18.9	—	16.5	18.5	—	18.1
2+ Adults; Ch. 6-15	19.8	19.0	19.7	15.3	16.1	19.4
1 Adult; Ch. 16-21	18.4	—	—	—	—	17.6
2+ Adults; Ch. 16-21	19.3	22.7	18.4	—	—	19.2
1 Retired Adult	—	—	—	—	—	—
2+ Retired Adults	18.8	—	17.5	—	—	18.6
Not Ascertained	20.2	—	—	—	—	17.9
Column Average	19.8	19.4	19.2	17.1	18.0	19.4
			III. Speed (MPH)			
1 Adult	33.0	39.2	34.0	36.5	—	33.8
2+ Adults	34.2	33.3	36.3	37.3	37.4	34.8
1 Adult; Ch. 0-5	34.5	—	—	26.3	—	31.2
2+ Adults; Ch. 0-5	36.9	32.1	36.7	34.7	39.9	36.4
1 Adult; Ch. 6-15	32.2	—	36.5	34.3	—	33.5
2+ Adults; Ch. 6-15	36.2	33.5	34.7	34.8	33.6	35.6
1 Adult; Ch. 16-21	39.4	—	—	—	—	38.7
2+ Adults; Ch. 16-21	35.4	34.5	34.8	—	—	35.3
1 Retired Adult	—	—	—	—	—	—
2+ Retired Adults	31.0	—	30.6	—	—	31.2
Not Ascertained	34.2	—	—	—	—	32.9
Column Average	35.1	33.8	35.5	34.9	37.0	35.1

* Blank cells represent fewer than 30 observations, and their values are thus not reported.

Table 16: DISTRIBUTION OF COMMUTE TRIP CHAINS BY LIFE CYCLE CATEGORY AND CHAIN TYPE (PERCENT)

	Trip Chain Type					
Life Cycle Category	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Total
1 Adult	55.6%	4.4%	34.8%	3.0%	2.2%	100.0%
2+ Adults	67.2	3.1	24.3	2.8	2.6	100.0
1 Adult; Ch. 0-5	44.8	6.5	15.4	32.0	1.3	100.0
2+ Adults; Ch. 0-5	60.5	6.2	22.0	9.1	2.1	100.0
1 Adult; Ch. 6-15	49.6	4.9	31.8	12.5	1.2	100.0
2+ Adults; Ch. 6-15	64.1	6.0	22.6	5.5	1.9	100.0
1 Adult; Ch. 16-21	66.5	4.2	25.4	3.0	0.9	100.0
2+ Adults; Ch. 16-21	70.0	4.8	20.6	2.1	2.6	100.0
1 Retired Adult	72.6	0.0	15.9	0.0	11.5	100.0
2+ Retired Adults	71.1	4.9	21.4	2.3	0.3	100.0
Not Ascertained	60.5	5.5	34.0	0.0	0.0	100.0
Column Average	64.0	4.7	24.2	4.9	2.2	100.0

Commuting Chains and Travel Mode

Work trips in complex commute chains by transit or mixed modes cover greater distances and are considerably longer in duration and slower in speed than simple commutes (see Table 17). Chaining has a substantial effect on duration and, consequently, speed. The auto only mode has an average speed of 35.1 mph, while the transit mode has an average speed of 19.1 mph.

Table 17: COMMUTING CHARACTERISTICS BY MODE AND COMMUTE CHAIN TYPE*

Mode	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Row Av.
			I. Distance (Miles)			
Auto Only	11.7	11.1	11.4	10.4	11.3	11.5
Transit Only	14.0	—	—	—	—	13.9
Auto/Transit	20.4	—	13.8	—	—	17.1
Auto/Other	5.6	7.5	9.5	5.9	—	7.9
Transit/Other	6.9	—	9.7	—	—	7.8
Auto/Transit/Other	—	—	—	—	—	9.0
Other Only	1.7	—	1.1	—	—	1.6
Average Distance	11.3	10.4	11.1	10.0	10.7	11.1
			II. Duration (Min.)			
Auto Only	20.0	19.5	19.3	17.6	18.2	19.6
Transit Only	42.9	—	—	—	—	43.5
Auto/Transit	37.9	—	35.8	—	—	35.7
Auto/Other	14.9	16.0	18.3	16.3	—	17.2
Transit/Other	27.1	—	37.7	—	—	33.0
Auto/Transit/Other	—	—	—	—	—	20.7
Other Only	12.1	—	12.8	—	—	11.8
Average Duration	20.6	19.4	20.1	17.4	18.8	20.2
			III. Speed (MPH)			
Auto Only	35.1	34.2	35.3	35.5	37.1	35.1
Transit Only	19.6	—	—	—	—	19.1
Auto/Transit	32.3	—	23.1	—	—	28.7
Auto/Other	22.5	28.0	31.1	21.9	—	27.7
Transit/Other	15.4	—	15.5	—	—	14.2
Auto/Transit/Other	—	—	—	—	—	26.0
Other Only	8.3	—	5.1	—	—	8.0
Average Speed	32.8	32.3	33.2	34.4	34.1	33.0

* Blank cells contain fewer than 30 observations, and their values are thus not reported.

Transit only commute chains are predominantly simple (94%), with only 5.1% of transit-based chains being complex from work to home (see Table 18). When auto and transit modes are mixed the rate of complex commute chaining from work to home increases to 28.2% and the rate of simple commute chains drops to 50.4%. When transit is combined with modes other than auto (principally walking), the rate of complex commute chaining from work to home increases again to 58.1%, and the simple commute chaining rate declines to 24.7%.

Table 18: DISTRIBUTION OF WORK TRAVEL BY MODE AND COMMUTE CHAIN TYPE (PERCENT)						
	Commute Chain Type					
Model	Simple	Complex To Work	Complex Fr. Work	Complex To/Fr. Work	Complex At Work	Total
Auto Only	64.6%	4.7%	23.7%	4.9%	2.1%	100.0%
Transit Only	94.0	0.5	5.1	0.0	0.4	100.0
Auto/Transit	50.4	8.2	38.2	3.3	0.0	100.0
Auto/Other	21.8	7.7	51.5	9.3	9.8	100.0
Transit/Other	24.7	11.5	58.1	0.0	5.6	100.0
Auto/Transit/Other	22.7	13.5	39.0	8.5	16.3	100.0
Other Only	82.5	4.6	10.2	1.5	1.1	100.0

Work Trip Time, Distance and Speed

The time, distance and speed of work trips contained within alternative commuting chains is presented in Table 19. Note that the figures in the table refer only to the work trip links in commuting chains.

A baseline for comparison is work trips in simple commute chains, represented by rows a and b in Table 19, which show work trip duration to be longer in the *to home* than the *to work* commute and, consequently, a lower speed on the *to home* commute. Trip lengths and total commuting distance are equivalent by definition for this chain type. As a result, there is a fairly close correspondence of the distances *to work* and *to home.*

Table 19: DURATION, DISTANCE AND SPEED OF WORK TRIPS IN ALTERNATIVE COMMUTE CHAINS

Chain Type	Time (Mins.)	Distance (Mi.)	Speed (MPH)
Simple Work			
a. To Work	20.0	11.1	33.3
b. To Home	21.2	11.2	31.7
Complex to Work			
c. To Work	15.9	8.5	32.1
d. To Home	18.3	9.4	30.8
Complex from Work			
e. To Work	20.1	11.1	33.1
f. To Home	15.1	7.7	30.6
Complex to & from Work			
g. To Work	16.0	9.4	35.2
h. To Home	12.4	6.6	31.9
Complex at Work			
i. To Work	18.2	11.0	36.3
j. To Home	19.7	10.6	32.3

The first category of complex work commutes is classified as chains that are "complex from home to work and simple from work to home" (rows c and d). The average work trip distance in the *to work* portion of the commute is 8.5 miles, which is nearly one mile shorter than the simple work-to-home return trip of 9.4 miles. The fastest component of this commute chain is the *to work* leg, with a speed of 32.1 mph.

The mirror of the first category is commute chains that are "simple from home to work and complex from work to home" (rows e and f). The *to work* trip component of the commute has a mean distance of 11.1 miles and a speed of 33.1 mph, whereas the final *from work* trip to home is only 7.7 miles with a speed of 30.6 mph.

The commute chains that are complex to and complex from work (rows g and h) have comparatively short but fast *to work* and *to home* trips. These work trip lengths can be compared to chains that are complex in the midday period but simple to and from work. These chains have work trip distances similar to simple commute chains but, for some reason, have faster speeds.

Effect of Trip Chaining on Work Trip Length

Estimates of the distance from home to work based on work trip data from the NPTS are downward biased when commute chains are complex because only the last leg to work or the last leg to home of complex commute chains are coded as work trips in the NPTS.

Chains that are simple-to-work and complex-to-home, and chains that are complex-to-work and simple-to-home provide the most direct evidence of the reduction of work trip distance due to chaining. For *Complex from Work* chains, the data in Table 19 indicate that the average work trip length in the *to home* portion is 31 percent shorter than its *to work* counterpart. Alternatively, in *Complex to Work* chains the average work trip length in the *to work* portion of the commute is nearly 10 percent shorter than the *to home* portion.

Two adjustments are made to reflect the composite downward effect of complex chaining on work trip distance and time in the NPTS. Chains that are complex on one end only are adjusted by using the direct home-to-work trip length for both ends. Chains that are complex both to-and-from are the most problematic. These are adjusted by using the average home-to-work trip length of *Complex from Work* commute chains and the *from work* average work trip length from *Complex to Work* commute chains.

Trip chaining-related adjustment factors for home-to-work distances and travel times are reported in Table 20. The distances and travel times of work trips in *Simple Work* and *Complex at Work* chains are unaffected because non-work trips are not contained in these chains' commutes. The distances and times of the *to work* trips in *Complex to Work* chains are increased by 10.6 and 15.1 percent, while the distances and times of the *to home* trips in *Complex from Work* chains are increased by 44.2 and 33.1 percent respectively. In the *Complex to & from Work* chains, *to work* trip distances and times are increased by 18.1 and 25.6 percent, and *to home* trip distances and times are increased by 42.4 and 47.6 percent.

Table 20: WORK TRIP DISTANCE AND TRAVEL TIME ADJUSTMENT FACTORS

Commute Chain Type	Distance	Time
Simple Work Chains		
To Work Trips	N.C.*	N.C.
To Home Trips	N.C.	N.C.
Complex to Work Chains		
To Work Trips	+10.6%	+15.1%
To Home Trips	N.C.	N.C.
Complex from Work Chains		
To Work Trips	N.C.	N.C.
To Home Trips	+44.2%	+33.1%
Complex to & from Work Chains		
To Work Trips	+18.1%	+25.6%
To Home Trips	+42.4%	+47.6%
Complex *at* Work Chains		
To Work Trips	N.C.	N.C.
To Home Trips	N.C.	N.C.

* No Change

These adjustments increase the mean distance and duration of work trips from 10.46 to 11.05 miles (5.64%) and 19.34 to 20.36 minutes (5.25%). The average work trip distance and duration in our analysis is slightly less than the averages reported in the *Summary of Travel Trends* (10.6 miles and 19.7 minutes) because work trips contained in invalid chains were not included, in addition to trips returning to work following mid-day non-work trips (which are coded as work trips in the NPTS). The percentages thus reflect the amount one should adjust work trips to account for trip chaining. Applying these adjustments (5.64% for miles and 5.25% for time) increases the averages reported in the *Summary of Travel Trends* to 11.2 miles and 20.7 minutes.

Conclusions

This report has examined trip chaining in the 1990 NPTS, noting patterns in three broadly defined categories: a) journey purpose and related travel characteristics; b) metropolitan characteristics; and c) characteristics of the traveler and his or her household. Regarding the first category, the trip chaining framework highlights the role of the commute as an organizing element in consolidating work and non-work activity. Trip chaining researchers commonly reach this conclusion, and its implications warrant emphasis: focusing solely on work trips understates their importance in household travel.

Examining work commutes in greater detail, we found that non-work stops were twice as likely to be contained in the homeward leg as in the commute to work. The apparent preference of the return commute for non-work travel activities is consistent with the contention that the penalties for late arrival at work are greater than late arrival on the return home (5, 12).

We observed that non-work chains were also more likely to be complex during peak commuting periods, which leads us to hypothesize that certain non-work activities also provide an organizational focus for other non-work trips. The scheduling of these journeys also favors the peak commuting periods, thus contributing to traffic congestion.

Complex chains are relatively more reliant on the automobile. Coupled with the evolving dispersion of work and non-work activities in metropolitan areas, conventional pedestrian and transit systems face a growing disadvantage in serving the mobility needs of a population that is increasingly engaging in complex trip chaining.

Regarding metropolitan characteristics we found the share of commute-related chains to increase with urban size. This increase is confined to simple commuting chains, and its causes are not evident. If congestion is positively related to metropolitan size, there would be a tendency for households to forego travel for purposes other than work. Also, households in larger metropolitan areas may be more likely to substitute in-home activities for out-of-home activities. Alternatively, transit accounts for a larger share of work trips in large metropolitan areas. Transit riders who make non-work stops in the course of their workday are more likely to be on foot, and the under-reporting of such walking trips has been a long-standing concern. A final possibility is that the demographic composition of large and small metropolitan areas is somewhat different. In particular, larger metropolitan areas have a greater share of households without children, whose trip-making is more work-oriented.

Trip chains in larger metropolitan areas were found to be neither more nor less complex than those in smaller metropolitan areas. However, metropolitan area residents are more likely to form complex trip chains than residents of non-metropolitan areas. The commutes of suburban residents were more likely to be complex than those of their central city and non-metropolitan counterparts, which may reflect differentials in commute distance and greater exposure to intervening non-work activities.

Increases in metropolitan size corresponded with increases in commuting distance and duration, and decreases in speed. Commuting distances in large metropolitan areas were not appreciably greater than distances in small metropolitan areas. This is consistent with the contention that large metropolitan areas are more likely to have a polynuclear form and, as a consequence, have similar commuting levels as smaller mononuclear cities (13).

Trip chaining patterns were quite distinct with respect to demographic factors. Generally, the share of complex chains is negatively related to household size. The presence of children in the household is also negatively related to complex chaining, and contributes to increases in the relative importance of non-work travel as well. As their children mature, the trip chaining patterns of family households more closely resemble those of single and multiple adult households.

Higher income households are more likely to form complex trip chains, and they also tend to organize a larger share of trips around the commute. This could reflect greater trip making frequency and corresponding opportunities for consolidating travel. It may also imply a greater marginal opportunity cost of time spent in travel for higher income households.

Women are more likely to form complex commute and non-work chains than men. Whether these differences can be explained in a household utility optimization framework is unclear. The "new home economics" perspective (14, 15) does not directly consider household travel activities, and doing so may yield fruitful insights on chaining differences between men and women, as well as trip chain patterns related to life cycle stage.

Work trips are representative of the distance between home and work only in simple commute chains. The inclusion of non-work trips in the commute results in work trip distances underestimating home-to-work distances by about 5 percent. Because complex commuting has become more prevalent, we can infer that this bias has increased over time.

In his evaluation Kitamura (16) distinguished the contributions of trip chaining research to better understanding of travel behavior from those which improved urban transportation models. He concluded that the former contributions were considerable, while the latter were scant. One possible reason for this disparity is that, until recently, there has been little incentive for urban transportation professionals and researchers to move beyond the established planning process and modeling framework. However, the focus of urban transportation planning is shifting toward travel behavior, and is becoming increasingly concerned with modifying travel behavior rather than reacting to it. Legislative and legal mandates addressing economic efficiency, land use, and environmental quality issues indicate that the days of the behaviorally anemic four-step models are numbered.

The path from models in current practice to their successors, however, is not clearly defined. Undoubtedly, the next generation models will need to be more capable of dealing with both the traditional transportation facility planning objectives and newly emerging policy issues. The need for more interplay between these two arenas will almost certainly require greater ability to derive travel outcomes from household, activity and transportation system conditions, as well as greater ability to project complex travel activity on a given system. Research on the former would be facilitated by an activity based survey of households rather than the current trip based format. This would permit more careful assessment of the substitutability among in-home work and non-work activities, for which travel is not required, and out-of-home alternatives, for which travel is required.

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Geographic Factors Explaining Worktrip Length Changes

Peter Gordon, Ph.D., and Harry W. Richardson, Ph.D.

Geographic Factors Explaining Worktrip Length Changes

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Geographic Factors Explaining Worktrip Length Changes

Appendix Tables

Executive Summary

Analyzing the 1983–1990 growth of almost 40 percent in U.S. vehicle miles travelled (VMT), Pisarski shows that much of it is accounted for by a 35.9 percent jump in average vehicle trip lengths (the other contributors being population growth, decline in vehicle occupancy, mode shifts to privately operated vehicles, and increased trips per capita). *Worktrip* VMT grew by even more, increasing by nearly 50 percent. Again, the contributors were more people and more workers, although the latter grew faster, largely because of greater female labor force participation. Although annual worktrips per worker fell slightly (from 450 to 425), there were in aggregate 8.2 percent more person worktrips. Because workers per vehicle fell (less transit use, fewer auto passengers) and because walking to work also diminished, the growth in vehicle worktrips grew much faster, 18.2 percent, in the 7-year interval. Yet, most of the worktrip VMT growth was explained by the almost 27 percent growth in average distance travelled (from 8.6 to 10.9 miles, one-way).

In spite of this and depending on how the data are aggregated, average worktrip *durations* either fell slightly or grew by much smaller percentages than distances. Either way, there were significant increases in average trip speeds. This casts doubt on reports of worsening congestion, such as those emanating from the Texas Transportation Institute (TTI). Of greater significance, however, is the idea that the welfare inferences to be drawn from the data will vary significantly, depending on whether increased trip distances (and TTI congestion measures) or whether higher average speeds and shorter (or nonincreasing) average trip times are emphasized. A third view reconciles the seeming paradox: suburbanization of jobs and residences is such that people are able to exercise the choice to live further away from activity centers but, because of higher speeds on less congested roads, are paying a modest cost (if any) in terms of extra time travelled.

This paper analyzes commuting data from the 1993 and 1990 NPTS. The results of this study support the third view.

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I. Introduction

Analyzing the 1983–1990 growth of almost 40 percent in U.S. vehicle miles travelled (VMT), Pisarski shows that much of it is accounted for by a 35.9 percent jump in average vehicle trip lengths (the other contributors being population growth, decline in vehicle occupancy, mode shifts to privately operated vehicles, and increased trips per capita).[1] *Worktrip* VMT grew by even more, increasing by nearly 50 percent. Again, the contributors were more people and more workers, although the latter grew faster, largely because of greater female labor force participation. Although annual worktrips per worker fell slightly (from 450 to 425), there were in aggregate 8.2 percent more person worktrips. Because workers per vehicle fell (less transit use, fewer auto passengers) and because walking to work also diminished, the growth in vehicle worktrips grew much faster, 18.2 percent, in the 7-year interval. Yet, most of the worktrip VMT growth was explained by the almost 27 percent growth in average distance travelled (from 8.6 to 10.9 miles, one-way).

In spite of this and depending on how the data are aggregated, average worktrip *durations* either fell slightly or grew by much smaller percentages than distances. Either way, there were significant increases in average trip speeds. This casts doubt on reports of worsening congestion, such as those emanating from the Texas Transportation Institute (TTI).[2] Of greater significance, however, is the idea that the welfare inferences to be drawn from the data will vary significantly, depending on whether increased trip distances (and TTI congestion measures) or whether higher average speeds and shorter (or nonincreasing) average trip times are emphasized. A third view reconciles the seeming paradox: suburbanization of jobs and residences is such that people are able to exercise the choice to live further away from activity centers but, because of higher speeds on less congested roads, are paying a modest cost (if any) in terms of extra time travelled.

Our previous work has shown that, where there are quicker commutes, they can be attributed to increased suburb-to-suburb commuting, although some of the changes are also accounted for by the mode changes cited earlier.[3] The plan of this research is to control for each of these effects so that commuting trends can be better understood. In much of what follows, person trips will be analyzed (to control for changes in vehicle occupancy), and metropolitan area trip data will be studied to test the effects of city size; most of the intertemporal comparisons will focus on private auto trips to control for mode choice changes.

II. Recent AHS and Census Findings

Recent reports analyze some of the new data on trends in U.S. commuting. The main points appear to be—

1. American Housing Survey (AHS) data show increasing median worktrip lengths for both home owners and renters, going back to 1974. In 1985, the respective distances were 7 and 10 miles; by 1989, they were 8 and 11 miles. These increases were across-the-board, with the notable exceptions of small town residents, individuals classified as in the poverty population, and Hispanics. In 1989, trips were longest for suburban residents. Between 1985 and 1989, there was a drop-off in trips less than four miles and an increase in all of the distance categories greater than five miles. Suburban trips had also become longer.[4]

2. AHS worktrip travel times had a median value of 19 minutes in 1985 (average of 20.9 minutes) and a corresponding 1989 median value of 20 minutes. However, there was no change in *metropolitan* area median trip times. The data show that just 9.0 percent of all urban commuters took trips that were longer than 45 minutes in 1989, *down slightly* from the 9.1 percent that did

so in 1985. The below-poverty population had shorter median commutes than the general population; their median commute declined from 18 to 17 minutes in the 4-year interval. Blacks had a higher median commute, which became longer in 1989; Hispanics showed no change, the same as the general population in 1989.[5]

3. Census comparisons are only possible for travel times. The increase was from an average of 21.7 minutes in 1980 to 22.4 minutes in 1990 (about 40 seconds).[6]

Neither the AHS or the Census survey questions address trip linking as part of the worktrip and are therefore difficult to use for this analysis. They do not allow analysts to control for the massive shifts in travel modes chosen, and they do not allow the effects of *trip chaining* to be held constant. For example, Liao has used NPTS data to show that trip chains that involve worktrips increased from 14.7 percent of all worktrips in 1983 to 19.2 percent in 1990.[7] Because only the NPTS data allow for the isolation of direct worktrips (a restriction we observed throughout our analysis), the Census and AHS data are difficult to interpret. The 40-second increase in average trip times recorded by the Census may simply reflect the increase in trip chaining.

To develop a clear picture of worktrip trends, we have used NPTS data and (unless otherwise noted) arranged our files as follows (and these arrangements distinguish our results from other studies that use the NPTS data):

1. Only nonstop (direct) worktrips are studied.
2. Observations with implausible values have been deleted (trips less than 1 mile or greater than 150 miles, trips less than 1 minute or greater than 150 minutes, trips less than 3 MPH or more than 80 MPH).
3. Only privately operated vehicle (POV) trips are included.
4. Only the trips of residents residing inside metropolitan areas are studied.[8]
5. AM-peak is 6–9 a.m., PM-peak is 4–7 p.m., and off-peak includes all weekend trips.
6. Because the 1983 and 1990 data were coded differently for trips of less than one-half mile, these were deleted to allow comparisons between the two years.

III. NPTS Commuting Data

III.1 1983 vs. 1990 Comparison of Trip Distributions

For all metropolitan area commuters, average commuting distances and durations increased in the 7 years between surveys, echoing the results for all U.S. commuters cited in the earlier reports. In terms of time and distance *distributions*, this is reflected in proportionately fewer short trips and proportionately more long trips. The change is apparent for all three major travel modes (privately operated vehicles, POVs with solo driver, and public transit), as shown in Tables 1A and 1B. Chi-square tests (Table 1C) reveal that the differences between distributions are, in every case, statistically significant. Nevertheless, in both years the number of commutes taking 45 minutes or more remains small, 7.3 percent in 1983 and 9.2 percent in 1990. The AHS data show a slightly higher share of 45 minute-plus commutes (10.1 percent in 1985 and 10.3 percent in 1989), but this may merely reinforce the importance of purging worktrip time estimates of worktrips that involve trip chaining because of their built-in bias toward longer commutes. Likewise, long-distance trips remain atypical; one-way commutes of 20 miles or more accounted for 12.3 percent of all Metropolitan Statistical Area (MSA) commutes in 1983 and 17.5 percent of all MSA commutes in 1990. Because the NPTS files allow for various disaggregations of metropolitan commuting, it is important to study these variations rather than merely focussing on averages (or medians).

III.2 Metropolitan Area Size Groups

Detailed *metropolitan area* commuting data by major size groups are shown in Tables 2A–2E. They display trip durations and distances for each of the two recent NPTS surveys (1983 and 1990). Trips are aggregated by place of residence of the respondent (inside central cities or outside central cities of metropolitan areas), time of day (peak periods vs. off-peak), and metropolitan area size class.

Though most (not all) average worktrip distances deteriorated in the 7 years (with the interesting exception of peak-hour commutes by inside-central-city residents of the largest metropolitan areas), there is a far more complex mixture of improvements and deteriorations when trip times are studied: for inside-central-city residents, trip durations improved during the morning peak in three of the five MSA-size groups (including the over-3-million group).[9] There were also trip-time improvements in three of the five groups for the afternoon peak. For outside-central-city residents, trip durations improved for two of the five groups. For the PM-peak, worktrip times fell in three of the five cases.

The pooled survey results on durations and distances were converted to data on trip speeds. The latter are more likely to be normally distributed and more appropriate for standard statistical testing. Trip speed comparisons are shown in Table 2D. *For all 30 of the survey comparisons shown,* trip speeds were higher in 1990 for all but two of them by statistically significant amounts. The results are substantially the same for drive-alone comparisons (Table 2E).

III.3 Urbanized Area Size Groups

Intertemporal comparisons between *urbanized area* size groups (selected for analysis because this is the file that makes a distinction between rail and nonrail cities) is made difficult by moderate changes in some of the category size cutoffs adopted in the 1990 NPTS (Tables 3A–3H). Again, there is a mixed picture of travel time and distance deteriorations as well as improvements; suburban residents in all groups travelled longer distances in 1990, regardless of time of day. Yet, again, the 30 intertemporal comparisons that are possible if the reclassification is ignored also show *across-the-board higher average speeds.* Apparently, urban development is such that there are opportunities to allow longer distances from activity centers to be enjoyed at little or no cost in extra time spent travelling.

The urbanized area tables show that the worst commutes (lowest average speeds) were in the largest urbanized areas with subways or rail transit available, largely because this group is dominated by older cities, especially New York. In fact, the contrasts between large cities with and without rail is instructive. In most cases, the areas with rail required lower speeds and more time to traverse similar (or even shorter) distances.

III.4 Cross-Sectional Tests

Cross-sectional ANOVA tests were conducted on the null hypothesis that average trip speeds were independent of metropolitan area size. Our previous cross-sectional analysis of the 1983 data revealed no significant differences between metro-area-size classes;[10] similar tests on the 1990 data yielded slightly different results. Table 4 shows that city size makes no differences for inside-central-city residents' AM-peak and off-peak worktrips. It is a factor, however, for inside-central-city residents' PM-peak travel and for all outside-central-city trips.

It is possible to expand the cross-sectional analysis by studying the 20 Consolidated Metropolitan Statistical Areas (CMSAs) for 1990 (the 1983 NPTS reported no such data). Table 5A indicates that the distributions of trip types are remarkably similar across the set of CMSAs. Table 5B shows that there is no simple relationship between trip speed and metropolitan area sizes. The middle-sized CMSAs appear to show the highest speeds. Even more intriguing is the finding that, while the most growth (more than 3 million people) took place in the Los Angeles CMSA, its central-city commuters' average speeds were eighth and its suburban commuters' average speeds were ninth. The accommodation made possible by suburbanization appears to be quite powerful.

III.5 Spatial Mismatch

Because the samples are small, metropolitan-area size-group data had to be aggregated into only three categories in order to test travel time and distance differences between blacks and whites. We used the 1990 NPTS data to test the widespread notion that the decentralization of employment works only to the advantage of white commuters (the "spatial mismatch" hypothesis). Table 6 shows that no systematic disadvantage for blacks was apparent. In black-white comparisons, holding income and metropolitan area constant, 30 pairs of means were calculated. Most showed no statistically significant differences. Of the seven cases where there were significant differences, five of them indicated *shorter* trips for black workers. While not all of the respondents in the NPTS data file are workers, the number of unemployed (those who responded that they were recently actively searching for work) necessarily showed too few worktrips to be included in the analysis. This inability to analyze the unemployed with the NPTS data leaves the spatial mismatch issue somewhat unresolved.

III.6 Household Commuting

Very little is known about how commuting behavior is affected by the number of workers in the household.[11] Table 7A shows that, almost without exception, the mode shifts that characterized the population (more solo travel in private autos, less carpooling, less transit use, less use of other modes) were common to households *no matter how many workers were present.*

Tables 7B–7D show average commuting times and distances *for the entire household* for the various modes. Because multiworker households are more likely to carpool than the population at large, it may be instructive to study Table 7C (drive-alone POVs). The longest trips were taken by workers from one-worker households. As workers were added, incremental household travel time and distance became smaller (the increments are even smaller for household members—Table 7D—that carpool, indicating that many of them do so with housemates). Also, while distances to work increased over the 7-year interval, travel time increased by smaller proportions. Average speeds must have risen. It appears that opportunities have arranged themselves in geographic space to cater to multiworker households.

III.7 Income and Gender

As a background to the discussion of gender, Table 8 shows the worktrips per capita by mode for both sexes in 1983 and 1990. Although the average annual number of worktrips per capita is significantly higher for men than for women (by 34.7 percent in 1990), female worktrips per capita have been increasing (by 9.1 percent, 1983–90) while male trips have declined (by 4.4 percent, 1983–90). Even more interesting, the growth in female worktrips has been restricted to private vehicles; female commuting by public transit and by other modes has declined.

Tables 8A and 8B examine the influences of income and gender on worktrip lengths, times, and speeds. Data on five broad income groups (in current dollars; unfortunately, constant dollar comparisons are difficult because the individual records list income group rather than dollar income) for both genders show that *everyone* travelled at significantly greater average speeds in 1990. Males travelled longer durations in 1990 only if they were in the highest income group. Females in the $15,000-$24,999 income group travelled significantly *shorter* durations in 1990, while those in the next income bracket experienced, on average, significantly longer durations. The lowest income males and the highest income males travelled greater distances in 1990. Middle-income females, on the other hand, travelled significantly longer distances in 1990. It makes little difference when drive-alone-only trips are studied (Table 8B). It appears that neither income nor gender is a good predictor of commuting differences. Rather, the changes described earlier, opportunities for faster speeds along less congested suburban roads that permit greater distances to workplaces, are available across-the-board.

III.8 Age and Gender

Similar findings are obtained when the age variable is tested (Tables 9A and 9B). *Everyone* drove faster in 1990, all except the oldest (65+) by statistically significant amounts. Likewise, everyone drove longer distances, usually by significant amounts, except for the youngest males (16–19) and the oldest two groups (60–64 and 65+) of both genders. Changes in trip durations were more complex: the youngest and oldest males had lower duration commutes, although the differences were not significant; all females experienced longer duration worktrips, although this was significant only for the three youngest and the oldest cohorts. The findings stratified by age and sex (Table 9B) are more or less the same for drive-alone commuters.

IV. Regional Differences

There are some data variables in the 1990 NPTS relevant to an evaluation of the effects of geographic factors on worktrips that were not included in the 1983 survey; hence, for these variables, 1983–1990 comparisons were impossible. Yet, there are some cross-sectional comparisons on these variables that merit attention.

Tables 10A–10D show the durations, distances, and speeds of nonstop worktrips for all private vehicle trips and for solo drivers by MSA size, time, and residence location for the nine Census Division regions in 1990. There appear to be no systematic regional differentials in worktrip lengths. Suburban worktrips are consistently longer than central-city-originating worktrips, although there is more regional variation among the central-city worktrip lengths. However, the regional outliers are not stable across city size classes.

V. The Effect of Residential Densities

The 1990 NPTS includes a measure of residential density by zip code. With the use of this variable, it is possible to obtain some insights into how urban structure affects worktrip lengths, times, and speeds. These insights can only be partial because the database tells us nothing about densities at destinations, and most worktrips are long enough to cross over zip code boundaries. Tables 11A and 11B show how nonstop worktrips vary among zip codes classified by residential density levels for all private vehicle commuters and for solo drivers. There is no systematic difference in worktrip lengths as the residential densities of commuter-origin areas change. However, there is a regular tendency for speeds to decline as residential densities increase. But, the rate of decline is very modest until very high densities (more than 10,000 persons per square mile) are reached. In consequence, travel times remain very stable (clustering around 20 minutes) from origin areas with very different densities; again, only when zip code densities rise above 10,000 persons per mile do peak trip commuting times increase sharply (above 50,000 persons per mile—characteristic of only a few locations in U.S. metropolitan areas—for off-peak trips). If travel by carpoolers (private vehicles with passengers; Table 11C) is studied, the findings are approximately the same.

VI. Conclusions

Our analysis of NPTS commuting data suggests much more benign conclusions than have been drawn from other recent studies that emphasize longer 1990 commutes. Considerable insight is gained by studying commuting *speeds* of the direct worktrips. Faster commuting was observed across-the-board; improvement was not restricted to a particular gender, ethnic group, income group, or age group, nor did place of residence matter (size of city or residence inside or outside of central cities). Our explanation is the increase of suburb-to-suburb commuting. More worktrips than ever now take place on faster and less congested roads. This is remarkable in light of the large number of nonwork trips that occur in all places, even in the peak periods. Tables 5A and 12 show that the distribution of trip types (nonstop worktrips, chained worktrips, all other trips) is strikingly stable across metropolitan areas and metropolitan-area size groups.

Our findings cast doubt on the many "doomsday" studies of congestion (including those that rely on TTI's synthetic congestion indices). What appears to be happening is that workers are able to locate further from activity centers (often on cheaper land) without paying the penalty of appreciably longer commutes. Our analysis has focused on the direct private vehicle worktrips (often also looking at single-occupant commutes, although this distinction made little difference) because we wanted to understand the changing spatial relationships that were taking place. It is, after all, the responsiveness of urban spatial structure to changing circumstances (including people's lifestyle choices) that is the true measure of the success of the land-use transportation system.

Endnotes

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6. Pisarski, Alan E., *New Perspectives in Commuting,* U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., July, 1992.

7. Liao, Yu-chun, "Trip Chaining in Urban Travel," paper presented at University of Southern California, Urban Economics Group Seminar, April, 1993.

8. Nonmetropolitan commuting data are summarized in Table A1 of the appendix.

9. Richard Forstal of the Census Bureau has recently completed calculations that show the extent to which central city redefinitions complicate population comparisons over the 7-year interval of our study. These are not major and it is difficult to identify the effects on the NPTS data.

10. Gordon, Peter, Richardson, H.W., and Kumar, Ajay, "Congestion, Changing Metropolitan Structure and City Size," *International Regional Science Review,* 12, pp. 45–56, 1989.

11. There were no serious problems in the 1990 NPTS with nonresponding households. The household response rate was 84 percent, and within the survey households travel information was collected for 87 percent of eligible persons (i.e., household members age 5 and older). In addition, nonresponse and poststratification adjustments were made to the NPTS survey weights. The only major difference is that another knowledgeable household member was permitted to provide proxy information for household members who were impossible to reach for interview.

Table 1A: NONSTOP WORKTRIPS: DISTRIBUTIONS OF DURATIONS, 1983 vs. 1990

	Privately Operated Vehicles		Privately Operated Vehicles Drive-Alone		Public Transit	
	1983	1990	1983	1990	1983	1990
< 15 min	38.88	36.68	39.54	36.76	7.18	9.40
15-29 min	39.44	38.52	40.82	39.03	26.44	26.47
30-44 min	14.34	15.63	13.38	15.42	24.14	28.27
45-59 min	3.98	5.25	3.55	5.15	17.53	14.54
60-89 min	2.93	3.09	2.38	2.87	20.40	15.52
> = 90 min	0.43	0.83	0.33	0.77	4.31	5.80

Table 1B: NONSTOP WORKTRIPS: DISTRIBUTIONS OF DISTANCES, 1983 vs. 1990

	Privately Operated Vehicles		Privately Operated Vehicles Drive-Alone		Public Transit	
	1983	1990	1983	1990	1983	1990
< 1 mi	3.77	2.27	3.61	2.17	0.00	0.41
1-4 mi	33.33	26.87	33.12	26.62	33.05	31.86
5-9 mi	25.88	24.66	27.74	24.90	30.17	23.20
10-19 mi	24.72	27.68	24.42	28.07	29.02	19.61
20-29 mi	8.15	10.53	7.69	10.40	3.74	10.87
30-49 mi	3.50	6.21	2.94	6.17	3.16	8.50
> = 50 mi	0.65	1.78	0.47	1.67	0.86	5.56

Note: Trips of less than one mile included since distances within the interval are not required.

TABLE 1C: CHI-SQUARE VALUES FOR TESTS OF THE NULL HYPOTHESIS THAT TRIP DURATION AND TRIP DISTANCE DISTRIBUTIONS DID NOT CHANGE BETWEEN 1983 and 1990

Mode	Duration	Distance
POV	24.003	162.401
POV (Drive Alone)	46.992	170.767
Public Transit	17.196	68.393

Rejection thresholds for the 99% level of significance are 15.09 (df = 5), and 16.81 (df = 6).

Table 2A: NONSTOP WORKTRIPS: MEAN TRIP TIMES AND DISTANCES, 1983 and 1990, TIME OF DAY, METROPOLITAN SIZE, PLACE OF RESIDENCE

MSA Population Size			AM-Peak	PM-Peak	Off-Peak
			Residing Inside Central Cities		
Below	T[1]	1983	15.2	17.2	13.6
250,000		1990	15.0	16.8	13.0
	D[1]	1983	6.7	7.6	6.2
		1990	7.8	9.6	7.0
250,000-	T	1983	15.1	15.2	15.7
499,999		1990	14.8	15.7	14.2
	D	1983	6.1	7.7	7.5
		1990	7.6	7.7	7.8
500,000-	T	1983	17.3	20.8	14.9
999,999		1990	17.9	17.9	16.1
	D	1983	8.5	9.3	6.9
		1990	10.2	9.2	9.2
1-3 Million	T	1983	18.3	20.8	17.9
		1990	19.5	21.3	17.8
	D	1983	8.7	8.3	8.7
		1990	10.4	11.1	9.7
Over	T	1983	28.8	29.4	23.0
3 Million		1990	22.9	24.6	21.7
	D	1983	12.7	12.3	10.4
		1990	11.7	11.8	12.1

[1] T refers to time in minutes, and D to distance in miles.

Table 2B: NONSTOP WORKTRIPS: MEAN TRIP TIMES AND DISTANCES, 1983, 1990 TIME OF DAY, METROPOLITAN SIZE, PLACE OF RESIDENCE

MSA Population Size			AM-Peak	PM-Peak	Off-Peak
			Residing Outside Central Cities		
Below	T[1]	1983	18.4	20.2	16.6
250,000		1990	19.1	20.0	20.4
	D[1]	1983	9.9	9.9	8.8
		1990	11.7	12.2	13.2
250,000-	T	1983	19.2	19.7	16.9
499,999		1990	19.3	21.9	19.4
	D	1983	10.6	9.9	8.8
		1990	12.0	13.6	12.5
500,000-	T	1983	22.5	25.5	21.7
999,999		1990	21.1	23.0	20.8
	D	1983	12.1	13.2	11.1
		1990	13.1	13.9	13.2
1-3 Million	T	1983	22.1	23.2	19.5
		1990	21.5	22.8	21.0
	D	1983	11.2	11.2	10.7
		1990	12.5	12.1	12.9
Over	T	1983	22.3	25.5	18.3
3 Million		1990	24.3	26.4	21.7
	D	1983	11.2	11.5	9.3
		1990	13.5	14.0	12.9

[1] T refers to time in minutes, and D to distance in miles.

Table 2C: NONSTOP WORKTRIPS: COMPARISON OF MEAN TRIP TIMES AND DISTANCES, 1983 AND 1990, TIME OF DAY, METROPOLITAN SIZE, PLACE OF RESIDENCE

Population Size			AM-Peak	PM-Peak	Off-Peak
	Residing Inside Central Cities				
Below 250,000	T[1]	83-90	Down	Down	Down
	D[1]	83-90	Up	Up	Up
250,000-499,999	T	83-90	Down	Up	Down
	D	83-90	Up	n/c	Up
500,000-999,999	T	83-90	Up	Down	Up
	D	83-90	Up	Down	Up
1-3 Million	T	83-90	Up	Up	Down
	D	83-90	Up	Up	Up
Over 3 Million	T	83-90	Down	Down	Down
	D	83-90	Down	Down	Up

Population Size			AM-Peak[a]	PM-Peak[a]	Off-Peak
	Residing Outside Central Cities				
Below 250,000	T[1]	83-90	Up	Down	Up
	D[1]	83-90	Up	Up	Up
250,000-499,999	T	83-90	Up	Up	Up
	D	83-90	Up	Up	Up
500,000-999,999	T	83-90	Down	Down	Down
	D	83-90	Up	Up	Up
1-3 Million	T	83-90	Down	Down	Up
	D	83-90	Up	Up	Up
Over 3 Million	T	83-90	Up	Up	Up
	D	83-90	Up	Up	Up

[1] T refers to time in minutes, and D to distance in miles.

Table 2D: NONSTOP WORKTRIPS: COMPARISON OF MEAN TRIP SPEEDS, 1983 AND 1990, TIME OF DAY, METROPOLITAN SIZE, PLACE OF RESIDENCE

MSA Population Size		AM-Peak	PM-Peak	Off-Peak
Residing Inside Central Cities				
Below 250,000	1983	25.0	22.9	24.6
	1990	29.6*	31.4*	30.2*
250,000-499,999	1983	23.5	25.0	24.9
	1990	29.9*	28.7	31.5*
500,000-999,999	1983	27.4	25.4	25.4
	1990	31.6*	29.3**	32.4*
1-3 Million	1983	27.6	24.2	27.5
	1990	30.7*	30.4*	31.7*
Over 3 Million	1983	25.9	25.5	25.9
	1990	30.0*	28.0	30.6*

Population Size		AM-Peak	PM-Peak	Off-Peak
Residing Outside Central Cities				
Below 250,000	1983	30.3	27.3	28.2
	1990	35.2*	34.1*	36.6*
250,000-499,999	1983	30.7	27.7	28.4
	1990	34.8*	35.1*	34.9*
500,000-999,999	1983	30.6	29.6	28.6
	1990	35.2*	34.9**	35.9*
1-3 Million	1983	28.4	27.0	29.9
	1990	33.5*	30.7*	34.7*
Over 3 Million	1983	28.1	25.8	27.3
	1990	31.8*	30.7*	33.1*

* Significantly greater than 1983 at the 99% confidence level.

** Significantly greater than 1983 at the 95% confidence level.

Table 2E: NONSTOP WORKTRIPS: COMPARISON OF MEAN WORKTRIP SPEEDS, 1983 AND 1990, PLACE OF RESIDENCE (PRIVATE VEHICLES, DRIVE-ALONE ONLY)

MSA Population Size		AM-Peak	PM-Peak	Off-Peak
Residing Inside Central Cities				
Below 250,000	1983	25.81	23.23	24.77
	1990	29.82**	31.57*	30.64*
250,000-499,999	1983	23.71	24.86	24.60
	1990	29.67*	29.30	32.27*
500,000-999,999	1983	28.05	26.93	25.27
	1990	30.95	28.50	32.99*
1-3 Million	1983	27.21	23.71	28.28
	1990	31.25*	30.80*	32.13*
Over 3 Million	1983	25.89	26.19	26.71
	1990	30.38*	28.38	30.40**

MSA Population Size		AM-Peak	PM-Peak	Off-Peak
Residing Outside Central Cities				
Below 250,000	1983	30.34	27.50	26.56
	1990	35.38*	35.00**	36.46*
250,000-499,999	1983	30.88	27.88	28.58
	1990	34.98*	35.08*	35.39*
500,000-999,999	1983	30.99	29.34	29.16
	1990	34.98**	35.07**	36.32*
1-3 Million	1983	28.42	27.02	30.15
	1990	33.60*	30.64*	34.60*
Over 3 Million	1983	27.40	26.36	27.44
	1990	31.76*	30.75*	33.28*

* Significantly greater than 1983 at the 99% confidence level.
** Significantly greater than 1983 at the 95% confidence level.

Table 3A: NONSTOP WORKTRIPS: COMPARISONS BY URBANIZED AREA SIZE, TIME OF DAY, PRIVATE VEHICLES, INSIDE CENTRAL CITY, 1990

	AM Peak			PM Peak			Off Peak		
Size of Urbanized Areas	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)
50,000-199,999	15.11	7.80	29.28	16.39	9.10	30.55	13.59	7.47	30.18
200,000-499,999	16.18	8.56	30.96	16.60	8.03	28.74	15.44	8.43	31.81
500,000-999,000	18.89	10.19	30.97	20.10	10.45	30.01	16.60	9.03	32.37
1 Million+ w/o Subway/Rail	20.67	11.04	31.23	23.54	11.89	29.69	19.19	11.15	32.13
1 Million+ w/ Subway/Rail	22.99	11.66	29.22	23.71	11.35	28.24	22.16	11.83	29.32

Table 3B: NONSTOP WORKTRIPS: COMPARISONS BY URBANIZED AREA SIZE, TIME OF DAY, PRIVATE VEHICLES, INSIDE CENTRAL CITY, 1983

	AM Peak			PM Peak			Off Peak		
Size of Urbanized Areas	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)
50,000-199,999	14.85	6.47	24.33	16.09	6.81	22.38	13.45	5.77	23.34
200,000-749,999	15.91	7.19	25.89	18.22	8.86	25.78	15.44	7.54	26.40
750,000-1,249,000	16.99	7.63	26.33	17.38	6.65	23.75	15.70	7.02	25.66
1.25 Million+ w/o Subway/Rail	21.88	11.22	28.76	24.21	10.66	26.20	19.97	10.12	28.62
1.25 Million+ w/ Subway/Rail	30.58	11.70	23.68	28.88	9.80	20.90	22.98	10.03	24.64

Table 3C: NONSTOP WORKTRIPS: COMPARISONS BY URBANIZED AREA SIZE, TIME OF DAY, PRIVATE VEHICLES, OUTSIDE CENTRAL CITY, 1990

	AM Peak			PM Peak			Off Peak		
Size of Urbanized Areas	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)
50,000-199,999	18.64	11.54	33.97	20.14	12.33	34.03	16.76	9.81	32.63
200,000-499,999	18.61	11.31	35.32	20.44	11.58	33.74	17.81	10.74	33.20
500,000-999,000	20.72	11.35	30.69	21.50	10.42	27.41	18.91	11.05	32.90
1 Million+ w/o Subway/Rail	22.37	12.57	33.37	24.82	12.66	31.03	20.41	12.14	34.90
1 Million+ w/ Subway/Rail	23.66	12.65	30.71	25.33	12.86	29.14	21.49	12.32	31.62

Table 3D: NONSTOP WORKTRIPS: COMPARISONS BY URBANIZED AREA SIZE, TIME OF DAY, PRIVATE VEHICLES, OUTSIDE CENTRAL CITY, 1983

	AM Peak			PM Peak			Off Peak		
Size of Urbanized Areas	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)
50,000-199,999	20.12	10.18	27.47	22.75	11.38	27.31	18.50	8.30	27.18
200,000-749,999	19.02	9.52	29.23	20.48	9.68	27.15	16.87	7.98	26.37
750,000-1,249,000	16.36	7.70	26.39	15.77	6.65	23.96	15.48	8.08	29.26
1.25 Million+ w/o Subway/Rail	21.17	10.99	29.35	25.07	12.26	27.09	16.41	8.29	28.60
1.25 Million+ w/ Subway/Rail	22.33	10.33	25.56	22.93	9.72	23.80	19.16	9.64	26.63

Table 3E: NONSTOP WORKTRIPS: COMPARISONS BY URBANIZED AREA SIZE, TIME OF DAY, SOLO DRIVERS, PRIVATE VEHICLES, INSIDE CENTRAL CITY, 1990

	AM Peak			PM Peak			Off Peak		
Size of Urbanized Areas	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)
50,000-199,999	14.68	7.71	29.45	16.13	9.16	30.93	13.45	7.56	30.65
200,000-499,999	16.00	8.33	30.62	16.16	7.69	28.72	14.93	8.36	32.65
500,000-999,000	18.86	10.19	31.09	20.11	10.44	30.02	16.42	9.21	33.17
1 Million+ w/o Subway/Rail	20.66	11.24	31.91	23.70	12.13	30.15	19.27	11.11	31.72
1 Million+ w/ Subway/Rail	23.71	12.20	29.51	23.96	11.69	28.56	21.50	11.08	29.41

Table 3F: NONSTOP WORKTRIPS: COMPARISONS BY URBANIZED AREA SIZE, TIME OF DAY, SOLO DRIVERS, PRIVATE VEHICLES, INSIDE CENTRAL CITY, 1983

	AM Peak			PM Peak			Off Peak		
Size of Urbanized Areas	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)
50,000-199,999	14.21	6.38	24.80	14.73	6.42	22.64	13.52	6.03	24.12
200,000-749,999	15.46	6.97	26.07	16.10	7.16	25.99	14.58	6.66	25.72
750,000-1,249,000	16.89	7.76	26.74	16.67	6.70	23.81	16.53	7.54	26.01
1.25 Million+ w/o Subway/Rail	21.75	10.90	28.49	24.92	10.65	25.89	19.51	10.07	29.48
1.25 Million+ w/ Subway/Rail	26.49	11.32	25.13	26.69	9.64	21.83	22.04	9.79	26.22

Table 3G: NONSTOP WORKTRIPS: COMPARISONS BY URBANIZED AREA SIZE, TIME OF DAY, SOLO DRIVERS, PRIVATE VEHICLES, OUTSIDE CENTRAL CITY, 1990

	AM Peak			PM Peak			Off Peak		
Size of Urbanized Areas	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)
50,000-199,999	17.93	10.76	33.71	20.70	12.75	34.32	16.91	9.72	32.42
200,000-499,999	18.65	11.47	35.77	19.99	10.84	32.91	16.81	9.81	32.97
500,000-999,000	20.59	11.37	30.78	21.20	10.82	28.04	18.78	11.02	33.05
1 Million+ w/o Subway/Rail	21.47	12.27	33.74	24.31	12.38	30.95	19.94	12.00	34.82
1 Million+ w/ Subway/Rail	23.22	12.33	30.48	24.61	12.61	29.10	20.58	11.83	31.73

Table 3H: NONSTOP WORKTRIPS: COMPARISONS BY URBANIZED AREA SIZE, TIME OF DAY, SOLO DRIVERS, PRIVATE VEHICLES, OUTSIDE CENTRAL CITY, 1983

	AM Peak			PM Peak			Off Peak		
Size of Urbanized Areas	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)	Duration (minutes)	Distance (miles)	Speed (mph)
50,000-199,999	22.45	11.00	27.36	26.75	11.75	25.12	19.44	8.44	25.53
200,000-749,999	18.48	9.41	29.88	19.71	9.19	27.02	16.21	7.75	26.58
750,000-1,249,000	14.85	6.78	26.45	14.47	6.04	23.80	14.65	7.29	28.50
1.25 Million+ w/o Subway/Rail	20.11	10.19	28.53	23.01	10.97	26.57	16.55	8.61	29.82
1.25 Million+ w/ Subway/Rail	22.10	9.97	25.38	22.86	9.84	24.38	19.54	9.52	26.14

Table 4: NONSTOP WORKTRIPS: ANOVA F-VALUES FOR NULL HYPOTHESIS THAT CITY SIZE DOES NOT AFFECT AVERAGE SPEEDS

Residence	AM-Peak		PM-Peak		Off-Peak	
	Work	Other	Work	Other	Work	Other
Inside Central Cities 1990	1.05 (0.3797)[a]	3.70 (0.0052)	2.65 (0.0321)	2.71 (0.0287)	1.48 (0.2067)	10.74 (0.0001)
Outside Central Cities 1990	8.11 (0.0001)	11.61 (0.0001)	9.00 (0.0001)	10.16 (0.0001)	5.77 (0.0001)	72.35 (0.0001)

[a] Significance levels are shown in parentheses.

Table 5A: DISTRIBUTION OF PERSON-TRIPS BY TRIP PURPOSE AND TIME OF DAY, 20 CMSAs, 1990 (all modes)

	Nonstop Worktrips			Worktrip Chains[a]			All Other Trips[b]		
	AM Peak	PM Peak	Off Peak	AM Peak	PM Peak	Off Peak	AM Peak	PM Peak	Off Peak
New York	7.57	5.30	7.16	1.13	3.65	4.42	4.34	10.60	55.83
Los Angeles	6.46	4.60	7.54	1.17	4.25	5.66	5.73	11.54	53.05
Chicago	6.63	4.03	8.71	1.17	3.39	5.84	4.37	9.88	55.97
San Francisco	5.66	4.15	6.10	0.78	3.17	5.37	6.39	12.59	55.78
Philadelphia	7.59	4.89	7.38	0.99	3.38	5.72	3.69	10.45	55.90
Detroit	5.76	3.74	7.12	1.21	3.39	4.40	3.94	12.13	58.31
Boston	6.56	3.77	6.56	1.62	3.95	5.21	3.23	11.59	57.50
Dallas	5.42	3.22	6.79	1.01	5.00	4.65	5.24	12.75	55.93
Houston	5.64	3.87	6.03	1.77	4.59	5.96	4.91	11.21	56.03
Miami	6.42	4.55	4.90	2.10	4.08	4.32	4.20	9.80	59.63
Cleveland	6.34	5.13	5.69	1.86	3.54	5.13	3.45	12.49	56.38
Seattle	6.46	4.76	6.80	1.81	4.42	7.14	5.33	10.54	52.72
Pittsburgh	5.76	3.65	7.64	0.89	3.10	4.87	4.65	10.41	59.03
Denver	7.57	4.34	7.07	0.99	3.97	3.47	4.71	13.77	54.09
Cincinnati	7.01	4.76	8.89	0.75	2.50	6.38	4.13	14.39	51.19
Milwaukee	5.54	3.50	7.73	1.17	3.21	3.79	4.66	12.83	57.58
Portland	4.88	5.04	6.67	1.95	2.11	3.58	3.58	11.06	61.14
Buffalo	7.25	3.63	7.25	0.90	3.63	4.23	3.93	11.48	57.70
Providence	3.46	2.07	7.37	0.92	1.15	3.92	2.53	5.30	73.27
Hartford	6.94	4.50	5.75	1.76	4.86	5.37	4.41	10.04	56.38
ALL U.S. MSAs	6.36	4.23	6.80	1.35	3.80	5.26	4.88	11.72	55.61

[a] Includes all legs of worktrip chains.
[b] Includes direct nonwork trips and all legs of nonwork trip chains.

Table 5B: NONSTOP WORKTRIPS: DURATIONS AND SPEEDS COMPARED WITH CMSA GROWTH (1980-1990) (private vehicles only)

CMSA	1990 Pop. (000)	Pop. Change (000) 1980-1990	% Pop. Change 1980-1990	Central City PM Peak - Worktrip Duration 1990 (min.)	Worktrip Duration 1990 (mins.) Residing Inside Central City	Worktrip Duration 1990 (mins.) Residing Outside Central City	Worktrip Speed 1990 (mph) Residing Inside Central City	Worktrip Speed 1990 (mph) Residing Outside Central City
Los Angeles	14,532	3034	26.4	25.5	23.7	26.0	31.7	33.6*
Dallas	3,885	954	32.6	25.5	21.0	18.8	33.0	36.1
San Francisco	6,253	885	16.5	16.6	19.7	21.9	29.6	33.9*
Houston	3,711	611	19.7	24.7	20.2	24.5	29.2	33.9*
Miami	3,193	549	20.8	19.8	19.7	23.5	32.8	28.6
New York	18,087	547	3.1	26.1	23.0	23.4	26.7	31.5*
Seattle	2,559	466	22.3	19.8	20.1	30.1	32.3	29.5
Denver	1,848	230	14.2	24.7	21.2	20.5	31.6	32.2
Philadelphia	5,899	218	3.8	22.3	22.6	22.1	34.8*	30.8
Boston	4,172	200	5.0	24.3	21.3	20.8	26.9	33.2*
Portland	1,478	180	13.9	18.3	16.8	21.6	26.7	35.0*
Chicago	8,066	129	1.6	30.4	27.8	23.3	32.5*	28.1
Cincinnati	1,744	84	5.1	19.2	17.4	22.0	31.5	34.8
Hartford	1,086	72	7.1	19.2	17.1	22.2	29.6	32.6*
Providence	1,142	59	5.5	16.7	12.5	19.1	39.0	35.1
Milwaukee	1,607	37	2.4	21.5	19.8	19.1	29.9	35.1*
Buffalo	1,189	-54	-4.4	16.7	17.7	24.1	35.5	34.3
Cleveland	2,760	-74	-2.6	19.1	19.8	20.3	27.1	30.4
Detroit	4,665	-88	-1.9	24.2	20.9	22.8	29.4	36.8*
Pittsburgh	2,243	-180	-7.4	28.8	22.2	17.7	25.6	29.5

* Significantly greater at the 95 percent level of confidence.

Table 6: RACIAL COMPARISONS: NONSTOP WORKTRIP DISTANCES AND DURATIONS BY MSA SIZE AND INCOME

MSA Size	Income Group	Blacks	Whites	Significantly Different at 95% Confidence*
Less than 1 million	< $ 15,000	6.07 mi	9.08 mi	YES
		14.29 mins	16.72 mins	NO
	$ 15,000 - $ 24,999	11.16 mi	9.62 mi	NO
		19.64 mins	17.32 mins	NO
	$ 25,000 - $ 39,999	7.54 mi	11.05 mi	YES
		16.22 mins	18.20 mins	NO
	$ 40,000 - $ 54,999	8.69 mi	12.04 mi	YES
		15.86 mins	19.49 mins	YES
	> $ 55,000	11.78 mi	11.21 mi	NO
		21.00 mins	18.44 mins	NO
1 - 3 million	< $ 15,000	6.71 mi	8.72 mi	YES
		17.06 mins	16.70 mins	NO
	$ 15,000 - $ 24,999	8.70 mi	10.67 mi	NO
		23.07 mins	18.90 mins	NO
	$ 25,000 - $ 39,999	10.36 mi	11.30 mi	NO
		20.42 mins	20.09 mins	NO
	$ 40,000 - $ 54,999	10.45 mi	11.36 mi	NO
		19.33 mins	20.63 mins	NO
	> $ 55,000	10.48 mi	12.95 mi	NO
		18.95 mins	22.23 mins	NO
Greater than 3 million	< $ 15,000	12.78 mi	15.32 mi	NO
		23.91 mins	21.67 mins	NO
	$ 15,000 - $ 24,999	10.47 mi	8.47 mi	NO
		26.29 mins	16.18 mins	YES
	$ 25,000 - $ 39,999	12.14 mi	11.82 mi	NO
		26.96 mins	21.81 mins	YES
	$ 40,000 - $ 54,999	12.61 mi	14.37 mi	NO
		25.78 mins	24.37 mins	NO
	> $ 55,000	13.65 mi	14.80 mi	NO
		29.02 mins	26.66 mins	NO

* Two-tailed t-tests.

Table 7A: NONSTOP WORKTRIPS: DISTRIBUTION OF COMMUTING MODE CHOICES BY NUMBER OF WORKERS PER HOUSEHOLD, 1983 and 1990

Number of Workers in Household	Private Drive -Alone		Private Drive w/Others		Public Transportation		All Others	
	1983	1990	1983	1990	1983	1990	1983	1990
1 Worker	73.93	82.56	15.21	9.73	8.00	5.90	2.85	1.81
2 Workers	75.36	82.48	16.49	12.45	5.13	3.80	3.02	1.28
3 Workers	72.06	78.13	20.11	15.98	—	4.41	4.45	1.49
More than 3 Workers	71.64	70.10	22.39	21.08	—	6.62	—	—
All	74.16	81.33	16.92	12.40	5.68	4.74	3.23	1.53

Note: Blank if fewer than 20 observations.

Table 7B: NONSTOP WORKTRIPS: MEAN HOUSEHOLD COMMUTING TIMES AND DISTANCES, 1983 and 1990 (all modes)

Number of Workers in Household	Time		Distance	
	1983	1990	1983	1990
1 Worker	36.4	37.6	15.9	20.2
2 Workers	50.6	52.9	23.5	29.2
3 Workers	64.0	65.8	30.3	35.2
More than 3 Workers	75.8	92.2	35.2	48.4

Note: Trips by workers on any day, not just travel day.

Table 7C: NONSTOP WORKTRIPS: MEAN HOUSEHOLD COMMUTING TIMES AND DISTANCES, 1983 and 1990 (private vehicles; drive alone)

Number of Workers in Household	Time		Distance	
	1983	1990	1983	1990
1 Worker	30.8	34.4	15.0	19.4
2 Workers	43.0	47.6	21.1	27.3
3 Workers	51.3	55.4	24.5	30.6
More than 3 Workers	55.6	67.6	28.3	39.0

TABLE 7D: NONSTOP WORKTRIPS: MEAN HOUSEHOLD COMMUTING TIMES AND DISTANCES, 1983 and 1990 (private vehicles; drive with others)

Number of Workers in Household	Time		Distance	
	1983	1990	1983	1990
1 Worker	39.3	36.2	19.1	20.3
2 Workers	39.4	41.8	19.5	22.5
3 Workers	41.6	39.6	22.5	22.5
More than 3 Workers	59.5	52.8	27.9	26.2

Table 8: ANNUAL PER CAPITA WORKTRIPS BY GENDER AND MODE, 1983 and 1990

	Mode								Percent Change 1983-1990
	Private		Public		Other[a]		Total		
	1983	1990	1983	1990	1983	1990	1983	1990	
Male	236.4	237.8	9.4	9.5	25.9	12.5	271.7	259.9	-4.4
Female	154.3	175.2	10.6	8.1	12.0	9.6	176.9	193.0	9.1

Note: [a] Include trips by bicycle, walking, school bus, taxi, airplane, Amtrak, moped and other modes.
Source: Travel Day data, Patricia S. Hu and Jennifer Young, *Summary of Travel Trends: 1990 NPTS*, 1992.

Table 8A: NONSTOP WORKTRIPS: TIME, DISTANCE, SPEED, BY INCOME GROUP, GENDER, AND YEAR (private vehicles)

Family Income Group		Time		Distance		Speed	
	Year	Male	Female	Male	Female	Male	Female
<$15,000	1983	18.17	16.12	8.98	7.31	27.52	25.59
	1990	20.21	16.05	12.33*	7.97	32.02*	30.51*
$15,000-	1983	20.47	18.36	9.95	8.79	27.36	25.80
$24,999	1990	19.76	16.63*	11.00	8.43	31.18*	29.89*
$25,000-	1983	21.73	16.90	11.37	7.39	28.52	25.25
$39,999	1990	20.71	18.71*	11.95	10.02*	32.95*	30.88*
$40,000-	1983	22.91	17.95	12.11	8.21	30.02	26.86
$54,999	1990	23.05	19.15	13.72*	10.52*	34.09*	31.44*
$55,000+	1983	21.86	21.45	10.99	9.73	27.91	26.43
	1990	25.20*	20.73	14.93*	10.96	34.03*	30.96*

* Significantly different at 95% level of confidence (two-tailed test).

Table 8B: NONSTOP WORKTRIPS: TIME, DISTANCE, SPEED, BY INCOME GROUP, GENDER, AND YEAR (drive alone)

Family Income Group		Time		Distance		Speed	
	Year	Male	Female	Male	Female	Male	Female
<$15,000	1983	17.11	15.91	8.61	7.43	28.20	26.85
	1990	17.89	15.78	10.03	7.91	31.64*	30.89*
$15,000-	1983	19.42	18.29	9.43	8.98	27.19	26.09
$24,999	1990	18.92	16.63	10.59	8.54	31.01*	30.08*
$25,000-	1983	20.19	16.33	10.29	6.95	28.11	25.10
$39,999	1990	20.22	19.01*	11.72*	10.31*	33.04*	31.15*
$40,000-	1983	22.02	17.63	11.53	8.23	29.91	27.07
$54,999	1990	22.97	19.70	13.64*	10.93*	34.12*	31.75*
$55,000+	1983	20.69	21.48	10.18	9.52	27.58	25.91
	1990	24.36*	19.96	14.56*	10.75	34.20*	31.12*

* Significantly different at 95% level of confidence (two-tailed test).

Table 9A: NONSTOP WORKTRIPS: TIME, DISTANCE, SPEED, BY AGE GROUP, GENDER, AND YEAR

Age Group	Year	Time			Distance			Speed		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
16-19	1983	15.32	11.48	13.60	7.87	4.88	6.53	26.87	24.08	25.62
	1990	15.22	15.34*	15.28	8.66	8.51*	8.59	32.75*	31.91*	32.37
20-29	1983	19.11	18.38	18.80	9.33	8.52	8.98	27.60	26.25	27.02
	1990	21.14	19.18	20.27	12.68*	10.84*	11.87	34.50*	33.17*	33.91
30-39	1983	23.60	17.98	21.11	12.36	8.66	10.72	29.24	27.34	28.40
	1990	23.75	20.02*	22.29	14.37*	10.89*	13.01	33.96*	31.61*	33.04
40-49	1983	21.91	17.11	19.99	11.61	7.93	10.14	29.21	26.35	28.07
	1990	24.08*	18.61*	21.69	14.24*	9.50*	12.16	33.65*	29.78*	31.96
50-59	1983	21.96	18.05	20.41	11.28	7.37	9.74	28.35	23.70	26.52
	1990	23.51	18.57	21.52	12.78*	8.84*	11.19	30.90*	27.72*	29.62
60-64	1983	18.68	16.46	17.96	8.29	6.82	7.82	24.93	20.99	23.65
	1990	19.41	15.79	17.95	9.62	7.44	8.74	28.95*	26.06*	27.78
65+	1983	20.52	21.03	20.79	7.79	7.62	7.70	23.87	20.51	22.06
	1990	18.82	16.24	17.88	9.18	5.56	7.85	27.55	21.97	25.51

* Significantly different at 95% level of confidence (two-tailed test).

Table 9B: NONSTOP WORKTRIPS: TIME, DISTANCE, SPEED, BY AGE GROUP, GENDER, AND YEAR (drive alone)

Age Group	Year	Time			Distance			Speed		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
16-19	1983	15.58	12.41	14.22	8.20	5.54	7.07	26.73	26.02	26.42
	1990	15.35	16.17*	15.71	9.09	9.22*	9.15	33.08*	32.82*	32.96
20-29	1983	17.94	17.53	17.77	8.82	8.20	8.56	27.68	26.48	27.18
	1990	20.69*	19.51*	20.18	12.47*	11.14*	11.89*	34.83*	33.49*	34.24
30-39	1983	22.46	17.71	20.48	11.73	8.66	10.45	29.02	27.63	28.44
	1990	22.96	20.03*	21.84	13.77*	11.09*	12.74	33.89*	31.77*	33.08
40-49	1983	20.22	16.85	18.91	10.17	7.55	9.15	28.81	26.17	27.78
	1990	23.21*	18.15	21.04	13.79*	9.41*	11.92	33.72*	30.11*	32.18
50-59	1983	20.31	18.45	19.64	10.48	7.60	9.44	28.42	24.09	26.86
	1990	23.31*	18.25	21.36	12.76*	8.57	11.15	31.13*	27.48*	29.73
60-64	1983	18.04	16.26	17.55	7.93	6.76	7.61	24.96	20.25	23.67
	1990	18.54	15.52	17.35	9.26	7.35	8.50	28.96*	26.20*	27.87
65+	1983	21.25	21.61	21.44	7.79	8.32	8.08	23.55	21.52	22.46
	1990	17.91	15.43*	17.15	9.02	5.80	8.03	26.99	22.71	25.68

* Significantly different at 95% level of confidence (two-tailed test).

Table 10A: NONSTOP WORKTRIPS: COMPARISONS BY REGION, MSA SIZE, TIME OF DAY, PRIVATE VEHICLES, 1990, COMMUTERS RESIDING INSIDE CENTRAL CITY

Size of MSA or CMSA of Household	Census Division	AM Peak Distance (minutes)	AM Peak Duration (miles)	AM Peak Speed (mph)	PM Peak Distance (minutes)	PM Peak Duration (miles)	PM Peak Speed (mph)	Off Peak Distance (minutes)	Off Peak Duration (miles)	Off Peak Speed (mph)
Less than 250,000	New England	19.14	10.52	32.91	18.94	9.88	34.49	10.76	5.12	27.77
	Middle Atlantic	10.63	5.00	24.75	13.75	6.75	29.00	14.07	6.50	22.28
	East North Central	14.07	7.05	29.29	15.38	6.55	25.08	12.31	6.17	28.79
	West North Central	11.14	5.37	27.71	14.06	6.76	29.59	10.19	5.02	31.34
	South Atlantic	18.33	10.37	31.75	19.16	11.59	34.16	16.44	9.73	32.09
	East South Central	16.69	10.08	33.57	38.57	32.57	36.00	13.33	8.07	32.88
	West South Central	14.05	6.78	28.65	15.43	8.98	33.25	13.42	8.20	32.51
	Mountain	15.00	7.68	29.82	13.00	8.05	31.95	14.67	7.26	29.89
	Pacific	11.60	4.87	23.23	11.29	4.00	20.09	12.04	5.57	24.99
250,000-499,000	New England	12.88	6.24	25.52	10.29	5.29	27.57	14.44	7.32	27.45
	Middle Atlantic	15.86	7.55	28.29	15.38	7.19	25.86	17.35	7.35	24.48
	East North Central	12.65	6.51	31.98	14.47	6.58	27.22	15.78	8.85	32.91
	West North Central	13.79	7.79	34.14	12.60	6.60	30.60	13.59	8.18	35.82
	South Atlantic	15.54	6.98	27.86	15.29	7.46	28.75	14.91	9.47	34.24
	East South Central	15.34	8.78	30.06	17.91	8.78	28.91	15.26	8.78	36.57
	West South Central	17.63	9.95	33.40	17.89	10.06	33.20	11.04	5.27	28.64
	Mountain	15.05	8.63	33.12	12.44	6.13	29.03	9.93	4.07	25.93
	Pacific	14.86	7.06	27.68	18.10	8.62	27.96	12.28	7.50	31.85
500,000-999,000	New England	14.97	7.12	25.29	12.35	5.50	26.44	19.89	12.33	33.15
	Middle Atlantic	18.79	11.58	31.49	16.93	9.00	25.37	13.11	5.92	26.26
	East North Central	16.68	9.64	32.46	16.47	9.47	31.23	14.14	7.44	29.43
	West North Central	12.33	7.56	35.68	12.29	7.86	36.56	9.50	5.25	35.77
	South Atlantic	17.73	9.14	28.82	20.68	9.37	26.11	18.51	10.58	30.52
	East South Central	20.44	13.77	36.22	19.40	13.08	35.76	15.35	8.27	32.99
	West South Central	18.29	10.84	35.27	18.41	9.41	31.81	16.58	10.65	37.63
	Mountain	16.65	8.18	29.33	17.15	7.62	26.75	17.48	10.00	35.09
	Pacific	22.09	9.36	22.65	20.27	8.64	24.06	16.44	9.78	31.78
1 - 3 Million	New England	17.75	10.15	32.29	19.03	8.46	26.99	12.88	6.83	32.82
	Middle Atlantic	20.33	9.46	29.74	24.83	11.25	30.83	18.48	9.19	31.48
	East North Central	19.06	9.84	30.19	20.72	10.84	30.63	17.43	9.49	31.73
	West North Central	19.02	9.84	30.85	22.92	11.56	30.70	17.69	9.96	32.47
	South Atlantic	20.95	10.94	30.83	21.93	10.06	28.40	18.07	9.25	29.67
	East South Central									
	West South Central	18.84	12.61	35.96	17.80	10.72	35.60	17.03	8.94	31.03
	Mountain	20.55	10.83	29.93	23.15	12.54	30.33	19.40	9.80	28.17
	Pacific	19.59	10.84	30.22	22.44	13.14	31.37	20.04	13.14	37.17
Greater than 3 Million	New England	18.58	9.82	29.63	19.69	10.59	28.97	15.73	7.75	28.65
	Middle Atlantic	27.03	12.32	27.48	29.29	13.04	27.31	22.70	9.90	25.23
	East North Central	23.59	12.94	31.10	27.40	13.31	28.21	25.54	16.88	32.85
	West North Central									
	South Atlantic	21.34	10.78	27.51	19.81	9.58	26.51	27.29	16.76	36.92
	East South Central									
	West South Central	19.77	10.65	31.92	25.11	12.72	30.82	19.19	11.27	31.51
	Mountain									
	Pacific	23.35	12.62	31.77	23.12	10.82	27.01	21.86	13.09	32.79

Table 10B: NONSTOP WORKTRIPS: COMPARISONS BY REGION, MSA SIZE, TIME OF DAY, PRIVATE VEHICLES, 1990, COMMUTERS RESIDING OUTSIDE CENTRAL CITY

Size of MSA or CMSA of Household	Census Division	AM Peak Distance (minutes)	AM Peak Duration (miles)	AM Peak Speed (mph)	PM Peak Distance (minutes)	PM Peak Duration (miles)	PM Peak Speed (mph)	Off Peak Distance (minutes)	Off Peak Duration (miles)	Off Peak Speed (mph)
Less than 250,000	New England	20.31	12.86	36.60	17.59	11.24	37.61	18.31	11.49	33.19
	Middle Atlantic	18.58	11.85	35.55	23.14	12.21	30.63	21.73	14.22	36.62
	East North Central	17.15	10.83	35.59	20.53	11.64	32.01	20.42	12.20	35.95
	West North Central	19.08	10.88	34.91	18.44	8.88	28.44	23.04	14.52	38.87
	South Atlantic	20.92	12.32	32.04	21.46	15.00	36.03	16.28	10.00	34.58
	East South Central	21.52	12.26	34.40	12.00	5.00	28.83	25.21	17.82	38.14
	West South Central	16.13	10.55	39.67	16.33	9.56	36.60	16.26	11.61	42.29
	Mountain	25.45	16.09	32.06	25.00	19.67	39.06	33.50	22.55	33.95
	Pacific	17.50	10.64	32.43	27.18	20.18	37.05	12.54	8.35	38.19
250,000-499,000	New England	19.86	14.30	35.78	18.81	10.76	30.77	27.54	20.18	37.38
	Middle Atlantic	25.66	16.19	35.36	26.31	16.19	37.19	16.51	9.38	32.10
	East North Central	17.40	10.49	33.97	19.42	13.79	36.52	18.65	12.20	35.79
	West North Central	21.55	13.64	36.45	24.38	14.88	36.63	16.25	8.50	28.15
	South Atlantic	21.02	12.55	35.42	25.07	14.36	32.26	22.55	14.35	35.18
	East South Central	17.90	10.51	34.20	21.45	13.68	37.61	17.89	13.64	40.43
	West South Central	15.38	9.08	33.15	16.67	10.67	35.25	16.90	10.25	34.41
	Mountain	16.38	10.00	31.75	25.00	15.00	36.67	20.75	10.50	29.00
	Pacific	10.60	6.10	34.28	15.82	9.71	35.28	15.70	9.00	33.13
500,000-999,000	New England	19.43	12.10	35.40	20.26	13.19	35.79	17.81	10.40	33.86
	Middle Atlantic	22.31	14.04	35.64	27.46	16.08	33.84	25.83	16.65	35.44
	East North Central	22.97	15.13	39.17	21.48	13.45	35.43	17.77	11.77	37.35
	West North Central	22.78	11.78	30.78	30.00	10.80	20.48	25.00	12.83	31.00
	South Atlantic	20.20	12.69	35.31	24.20	14.31	35.76	20.43	12.83	36.56
	East South Central	23.07	14.46	35.40	24.09	14.45	36.11	18.61	12.09	36.55
	West South Central	18.96	11.50	33.75	23.25	14.80	34.99	26.63	16.16	34.30
	Mountain	20.83	9.58	29.92	20.00	10.00	30.37	25.00	10.86	31.00
	Pacific	20.53	11.67	30.35	18.86	8.86	27.16	26.87	21.17	42.76
1-3 Million	New England	21.92	13.24	33.48	23.17	12.29	30.34	21.32	12.94	33.73
	Middle Atlantic	19.44	10.99	32.40	20.38	11.89	32.21	21.04	12.16	32.63
	East North Central	20.59	11.91	33.26	21.96	11.99	30.56	19.12	11.87	35.02
	West North Central	21.23	13.71	35.67	23.80	13.12	31.95	18.01	11.19	36.95
	South Atlantic	22.24	12.68	33.71	20.95	11.09	30.77	22.97	14.50	34.65
	East South Central	21.67	14.78	33.47	20.56	9.33	27.52	17.40	11.40	29.40
	West South Central	17.57	10.26	32.46	24.53	12.40	31.81	17.95	10.40	34.18
	Mountain	18.50	10.31	32.93	24.03	12.17	30.16	19.46	11.24	34.10
	Pacific	25.45	13.66	33.18	27.14	12.80	29.31	25.69	15.60	35.31
Greater than 3 Million	New England	21.89	13.23	32.46	25.33	14.98	31.63	17.14	10.86	33.02
	Middle Atlantic	24.23	13.40	31.11	25.48	12.95	29.12	22.24	12.60	32.28
	East North Central	24.64	13.27	31.03	25.34	13.25	30.71	20.80	12.37	32.93
	West North Central									
	South Atlantic	30.55	14.09	28.38	31.78	15.59	29.59	22.63	12.14	31.81
	East South Central									
	West South Central	21.37	13.09	37.74	23.95	13.32	34.06	21.25	13.09	32.49
	Mountain									
	Pacific	23.67	13.77	32.79	28.00	15.21	32.13	24.08	15.51	35.49

Table 10C: NONSTOP WORKTRIPS: COMPARISONS BY REGION, MSA SIZE, TIME OF DAY, SOLO DRIVERS, PRIVATE VEHICLES, 1990, COMMUTERS RESIDING INSIDE CENTRAL CITY

Size of MSA or CMSA of Household	Census Division	AM Peak Distance (minutes)	AM Peak Duration (miles)	AM Peak Speed (mph)	PM Peak Distance (minutes)	PM Peak Duration (miles)	PM Peak Speed (mph)	Off Peak Distance (minutes)	Off Peak Duration (miles)	Off Peak Speed (mph)
Less than 250,000	New England	19.46	10.79	33.44	18.94	9.88	34.49	11.00	5.68	29.75
	Middle Atlantic	10.63	5.00	24.75	13.75	6.75	29.00	14.07	6.50	22.28
	East North Central	12.56	6.51	28.65	12.54	5.92	25.43	11.02	5.57	29.14
	West North Central	11.07	5.14	26.74	14.33	6.60	27.94	9.95	5.05	32.26
	South Atlantic	17.84	10.00	31.24	18.10	11.06	34.19	16.84	9.79	30.48
	East South Central	15.50	10.10	35.44	61.67	59.00	50.00	11.82	7.00	32.91
	West South Central	14.20	7.23	30.66	15.67	9.30	34.28	13.83	8.69	33.45
	Mountain	12.11	6.81	30.21	13.28	8.22	31.64	10.91	6.05	30.05
	Pacific	12.07	5.07	23.17	11.29	4.00	20.09	12.21	6.05	26.46
250,000-499,000	New England	11.36	5.07	24.74	11.17	5.83	28.17	13.68	6.73	27.22
	Middle Atlantic	15.67	7.52	28.50	16.83	8.58	28.64	16.67	7.27	24.87
	East North Central	12.51	6.34	31.64	14.47	6.58	27.22	15.44	9.06	33.98
	West North Central	14.08	7.62	32.15	12.60	6.60	30.60	13.81	8.06	34.31
	South Atlantic	14.56	6.53	27.17	15.30	7.52	28.96	14.90	9.73	35.06
	East South Central	15.57	9.07	30.39	18.67	9.33	29.95	10.32	5.47	38.11
	West South Central	17.63	9.95	33.40	17.89	10.06	33.20	11.23	5.77	31.12
	Mountain	16.44	9.56	34.33	12.27	6.20	29.63	9.50	3.75	23.62
	Pacific	14.55	6.70	26.99	16.84	7.84	27.54	12.52	7.65	31.71
500,000-999,000	New England	14.44	6.93	24.93	12.00	5.59	26.52	20.59	13.48	34.37
	Middle Atlantic	15.75	8.88	30.46	11.42	4.25	22.31	13.09	6.44	28.48
	East North Central	14.32	7.79	31.75	13.21	6.93	30.00	14.06	7.33	29.56
	West North Central	13.60	7.40	30.42	13.67	7.67	30.30	9.45	5.09	35.20
	South Atlantic	17.87	9.27	29.13	20.97	9.72	26.91	17.86	10.19	30.64
	East South Central	20.50	14.02	36.46	19.48	13.22	35.69	14.93	8.30	33.94
	West South Central	18.33	10.71	34.70	19.44	9.72	30.62	16.74	10.74	37.58
	Mountain	16.07	6.93	26.57	17.33	7.42	25.65	15.89	9.32	34.89
	Pacific	21.44	7.11	20.72	19.22	6.22	22.44	17.63	10.63	32.94
1-3 Million	New England	17.16	10.21	33.63	17.75	7.88	28.20	12.73	7.00	33.16
	Middle Atlantic	17.94	9.67	32.79	23.13	12.00	35.83	19.27	9.73	32.69
	East North Central	19.31	10.17	30.71	20.90	11.10	31.20	17.31	9.69	32.47
	West North Central	18.02	10.06	32.31	23.61	12.52	32.15	17.38	10.17	32.21
	South Atlantic	21.22	10.95	30.21	21.92	9.92	27.88	19.30	9.82	29.22
	East South Central									
	West South Central	18.15	12.55	37.18	17.62	10.38	34.58	17.43	9.43	32.71
	Mountain	20.89	11.06	30.29	23.21	12.37	29.89	20.81	10.57	28.45
	Pacific	20.64	11.58	30.99	23.07	13.50	31.16	21.17	13.99	37.27
Greater than 3 Million	New England	19.70	10.52	29.76	20.14	10.98	28.94	16.78	8.41	29.04
	Middle Atlantic	28.60	13.03	27.18	29.86	13.50	27.55	22.59	10.46	26.74
	East North Central	24.12	13.62	32.23	28.12	13.83	28.96	20.92	10.62	28.97
	West North Central									
	South Atlantic	21.92	11.43	28.44	19.69	9.15	25.50	26.81	17.68	38.99
	East South Central									
	West South Central	20.14	10.92	32.01	25.21	13.13	31.45	17.66	9.88	30.21
	Mountain									
	Pacific	23.47	12.56	32.68	23.22	10.90	27.71	21.89	13.24	32.89

Table 10D: NONSTOP WORKTRIPS: COMPARISONS BY REGION, MSA SIZE, TIME OF DAY, SOLO DRIVERS, PRIVATE VEHICLES, 1990, COMMUTERS RESIDING OUTSIDE CENTRAL CITY

Size of MSA or CMSA of Household	Census Division	AM Peak Distance (minutes)	AM Peak Duration (miles)	AM Peak Speed (mph)	PM Peak Distance (minutes)	PM Peak Duration (miles)	PM Peak Speed (mph)	Off Peak Distance (minutes)	Off Peak Duration (miles)	Off Peak Speed (mph)
Less than 250,000	New England	20.60	13.11	36.96	17.62	11.08	36.88	19.45	12.23	32.63
	Middle Atlantic	17.74	10.53	32.94	23.92	12.83	30.95	23.73	15.10	34.84
	East North Central	16.69	10.58	36.29	21.42	12.39	34.12	21.50	13.18	38.23
	West North Central	19.91	11.36	35.08	18.33	9.92	32.08	19.41	13.45	40.20
	South Atlantic	20.30	12.04	32.17	22.21	15.83	36.66	15.28	9.42	34.63
	East South Central	21.52	12.26	34.40	12.00	5.00	28.83	27.39	19.00	36.64
	West South Central	15.69	10.36	40.30	16.58	9.81	37.32	15.78	10.96	41.30
	Mountain	27.50	17.40	31.67	25.00	19.67	39.06	34.14	23.05	33.85
	Pacific	19.00	12.09	34.18	20.50	13.63	34.88	12.32	7.68	36.23
250,000-499,000	New England	17.05	10.71	34.57	19.45	11.15	30.81	24.82	17.74	37.37
	Middle Atlantic	24.58	15.13	34.56	27.18	17.09	37.94	16.88	9.72	31.99
	East North Central	17.31	10.71	34.73	19.27	13.76	36.54	18.50	12.41	36.48
	West North Central	21.55	13.64	36.45	24.38	14.88	36.63	17.57	9.57	30.94
	South Atlantic	21.25	12.47	35.37	24.27	12.92	30.78	23.08	14.89	35.88
	East South Central	18.49	10.86	34.11	21.52	13.62	37.25	18.16	13.88	40.55
	West South Central	16.50	10.30	35.30	16.25	11.13	37.63	17.06	10.44	35.13
	Mountain	16.75	10.83	35.06	20.00	12.50	37.50	25.83	13.33	31.67
	Pacific	11.11	6.56	35.42	15.60	9.47	35.58	15.44	8.88	33.60
500,000-999,000	New England	19.63	12.29	34.79	20.07	12.79	35.07	18.80	11.01	33.86
	Middle Atlantic	22.40	14.38	36.76	28.71	16.88	34.25	23.95	16.00	37.49
	East North Central	23.83	15.47	37.80	22.69	14.12	34.41	18.03	12.07	38.01
	West North Central	23.75	12.00	29.63	30.00	10.80	20.48	25.00	12.83	31.00
	South Atlantic	19.35	11.73	34.54	20.49	12.09	35.12	20.32	12.87	36.96
	East South Central	23.47	14.71	36.24	25.26	16.33	39.06	17.88	11.54	37.01
	West South Central	18.91	11.35	33.26	23.61	15.33	35.32	29.13	17.75	34.92
	Mountain	16.88	8.25	28.75	18.75	10.25	34.20	17.00	9.20	34.40
	Pacific	21.38	11.92	28.87	21.67	10.17	26.69	28.00	21.59	40.96
1-3 Million	New England	22.46	13.66	33.67	23.56	12.59	30.08	21.22	13.01	33.98
	Middle Atlantic	19.92	11.47	32.82	22.17	13.00	32.52	21.63	12.57	33.08
	East North Central	20.26	11.81	33.43	22.46	12.47	30.77	18.66	11.54	34.73
	West North Central	20.41	13.02	35.26	22.15	12.00	31.62	18.14	11.45	36.49
	South Atlantic	22.41	12.87	33.84	21.29	11.32	31.16	20.75	12.92	34.81
	East South Central	22.50	16.00	35.15	18.57	9.71	30.17	17.40	11.40	29.40
	West South Central	17.57	10.26	32.46	26.14	13.14	29.80	17.72	9.89	32.98
	Mountain	19.02	10.35	32.43	23.79	11.68	29.24	20.14	11.02	32.25
	Pacific	22.64	12.74	33.01	25.58	11.79	28.68	23.51	15.65	36.21
Greater than 3 Million	New England	20.74	12.50	32.49	24.44	14.44	31.53	17.05	10.82	33.11
	Middle Atlantic	23.73	13.03	30.74	24.25	12.52	28.89	21.58	12.26	32.09
	East North Central	24.53	13.09	30.94	25.54	13.45	30.97	19.90	11.94	33.44
	West North Central									
	South Atlantic	30.91	14.39	28.62	31.83	16.02	30.31	21.96	12.45	33.18
	East South Central									
	West South Central	21.50	13.12	38.04	24.32	13.32	33.98	21.45	13.49	32.99
	Mountain									
	Pacific	22.75	13.34	33.07	27.58	15.12	32.35	23.77	15.24	35.39

Table 11A: NONSTOP WORKTRIPS: COMPARISONS BY RESIDENTIAL DENSITY OF COMMUTERS' RESIDENTIAL ZIP CODE, PRIVATE VEHICLES, 1990

Population Density, Commuter Residence Zip Code	AM Peak Duration (minutes)	AM Peak Distance (miles)	AM Peak Speed (mph)	PM Peak Duration (minutes)	PM Peak Distance (miles)	PM Peak Speed (mph)	Off Peak Duration (minutes)	Off Peak Distance (miles)	Off Peak Speed (mph)
1000-1999	20.65	11.72	32.43	21.80	12.02	31.81	19.46	11.21	32.47
2000-2999	20.36	10.63	30.93	22.60	11.41	29.56	18.49	10.78	33.85
3000-3999	19.09	9.82	29.42	20.63	9.81	27.74	16.09	8.66	30.39
4000-4999	20.69	10.53	29.33	20.87	9.92	28.72	20.18	11.97	32.33
5000-7499	20.30	10.49	29.76	24.93	11.55	27.21	19.50	10.17	30.02
7500-9999	20.31	10.64	29.32	21.13	9.95	26.87	20.34	11.21	31.05
10000-49999	24.64	11.37	27.46	27.36	10.89	24.76	19.96	8.56	26.45
50000+	35.42	9.42	17.68	37.50	10.00	17.00	27.17	9.83	19.44

Table 11B: NONSTOP WORKTRIPS: COMPARISONS BY RESIDENTIAL DENSITY OF COMMUTERS' RESIDENTIAL ZIP CODE, SOLO DRIVERS, PRIVATE VEHICLES ONLY, 1990

Population Density, Commuter Residence Zip Code	AM Peak Duration (minutes)	AM Peak Distance (miles)	AM Peak Speed (mph)	PM Peak Duration (minutes)	PM Peak Distance (miles)	PM Peak Speed (mph)	Off Peak Duration (minutes)	Off Peak Distance (miles)	Off Peak Speed (mph)
1000-1999	20.22	11.35	32.19	21.52	11.63	31.34	18.96	10.92	32.81
2000-2999	19.89	10.59	31.23	22.40	11.35	29.57	17.90	10.55	33.57
3000-3999	18.95	9.86	29.92	20.38	9.71	27.87	15.57	8.47	30.87
4000-4999	20.28	10.38	29.53	20.49	9.94	29.08	19.15	10.68	32.06
5000-7499	20.01	10.33	29.75	23.75	11.23	27.45	19.29	10.28	30.34
7500-9999	20.68	10.91	29.59	21.75	10.42	27.17	20.51	11.60	31.51
10000-49999	25.66	11.79	27.75	26.93	10.90	25.09	19.60	8.60	26.98
50000+	34.44	9.00	17.52	40.00	11.67	19.33	30.00	13.67	24.87

Table 11C: NONSTOP WORKTRIPS: COMPARISONS BY RESIDENTIAL DENSITY OF COMMUTERS' RESIDENTIAL ZIP CODE, PRIVATE VEHICLES WITH PASSENGERS ONLY, 1990

Population Density, Commuter Residence Zip Code	AM Peak Duration (minutes)	AM Peak Distance (miles)	AM Peak Speed (mph)	PM Peak Duration (minutes)	PM Peak Distance (miles)	PM Peak Speed (mph)	Off Peak Duration (minutes)	Off Peak Distance (miles)	Off Peak Speed (mph)
1000-1999	23.87	15.08	34.98	23.60	14.62	35.24	22.57	13.22	29.87
2000-2999	23.18	10.74	29.04	23.97	11.82	29.52	20.99	12.05	35.95
3000-3999	20.15	9.63	26.08	22.35	10.48	26.89	19.09	9.78	27.73
4000-4999	22.80	11.00	27.77	22.15	9.58	26.94	25.74	19.06	33.63
5000-7499	21.29	10.85	29.58	31.15	13.13	25.90	20.44	9.70	28.58
7500-9999	18.24	9.14	27.87	18.69	8.15	25.69	19.25	9.13	28.82
10000-49999	20.76	9.89	26.70	25.76	9.76	24.00	21.06	8.34	24.49
50000+	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 12: DISTRIBUTION OF PERSON-TRIPS BY TRIP PURPOSE AND TIME OF DAY, MSA SIZE, 1990 (all modes)

		Nonstop Worktrips			Worktrip Chains[a]			All Other Trips[b]		
		AM Peak	PM Peak	Off Peak	AM Peak	PM Peak	Off Peak	AM Peak	PM Peak	Off Peak
Below	1983	5.49	2.68	6.69	1.17	3.14	5.45	5.39	11.78	58.21
250,000	1990	5.18	3.13	6.76	1.46	3.49	5.84	5.33	12.61	56.21
250,000-	1983	6.53	3.67	7.44	1.17	3.38	4.77	5.85	12.50	54.69
499,999	1990	5.91	3.65	6.28	1.25	3.99	5.52	5.59	12.80	55.00
500,000-	1983	5.63	2.86	6.14	1.08	2.80	6.65	6.42	12.15	56.28
999,999	1990	6.01	4.01	6.25	1.50	3.65	5.13	4.79	12.46	56.19
1-3 Million	1983	6.62	4.19	4.88	1.48	3.29	4.25	5.64	12.05	55.61
	1990	6.58	4.56	6.81	1.45	3.89	5.20	4.77	11.46	55.28
Over 3	1983	6.97	4.51	8.03	0.75	2.42	3.86	6.84	10.41	56.21
Million	1990	6.82	4.59	7.14	1.20	3.81	5.07	4.64	11.03	55.69
Total	1983	6.37	3.76	7.09	1.16	3.01	4.77	6.03	11.71	56.09
	1990	6.35	4.23	6.79	1.35	3.80	5.26	4.88	11.72	55.62

[a] Includes all legs of worktrip chains.
[b] Includes direct nonwork trips and all legs of nonwork trip chains.

Appendix Table 1: NONSTOP WORKTRIPS: MEAN TRIP TIMES, DISTANCES, SPEEDS, 1983 and 1990, NONMETROPOLITAN AREAS (all modes)

		AM-Peak	PM-Peak	Off-Peak
Time	1983	18.25	19.19	17.73
	1990	18.22	19.66	19.08
Distance	1983	9.60	10.18	9.74
	1990	11.61	12.53	12.58
Speed	1983	28.07	28.05	28.45
	1990	34.47*	34.08*	35.94*

* Significantly faster at 99% confidence level.

Appendix Table 2: METROPOLITAN AREA SIZE CLASS POPULATION GROWTH, 1980-90 (population in 000's)

	1980	1990	Average Annual Growth Rate
All metro areas	172,678(284)*	192,726(284)	1.104%
3 million	10,077(2)	10,808(2)	0.703
1-3 million	7,455(4)	9,145(6)	2.064
500,000-999,999	10,914(16)	10,677(16)	-0.220
250,000-499,999	12,217(34)	14,115(40)	1.455
less than 250,000	132,015(228)	147,981(220)	1.147

Appendix Table 3: NONSTOP WORKTRIPS: COMPARISONS BY REGION, MSA SIZE, TIME OF DAY, PRIVATE VEHICLES ONLY, 1990, COMMUTERS RESIDING INSIDE CENTRAL CITY

MSA Population Size Class	Census Region	AM Peak Distance (minutes)	AM Peak Duration (miles)	AM Peak Speed (mph)	PM Peak Distance (minutes)	PM Peak Duration (miles)	PM Peak Speed (mph)	Off Peak Distance (minutes)	Off Peak Duration (miles)	Off Peak Speed (mph)
Less than 250,000	Northeast	17.30	9.32	31.15	17.95	9.29	33.45	11.60	5.47	26.37
	North Central	12.76	6.29	28.58	14.89	6.63	26.75	11.18	5.55	30.15
	South	16.14	8.65	30.50	19.00	12.10	33.88	14.60	8.80	32.38
	West	13.89	6.76	27.67	12.54	6.96	28.76	13.46	6.48	27.64
250,000-499,000	Northeast	14.56	6.97	27.09	13.83	6.61	26.38	15.62	7.33	26.25
	North Central	12.96	6.86	32.58	14.08	6.58	27.92	15.33	8.71	33.50
	South	15.90	8.22	29.77	16.94	8.65	30.04	13.77	7.93	33.10
	West	14.93	7.60	29.56	15.65	7.54	28.43	11.53	6.40	29.96
500,000-999,000	Northeast	16.34	8.72	27.51	14.24	6.94	26.00	16.41	9.04	29.61
	North Central	15.42	9.03	33.39	15.25	9.00	32.78	12.98	6.90	31.01
	South	18.72	11.11	33.37	19.53	10.27	30.52	16.76	9.83	33.88
	West	18.79	8.64	26.70	18.58	8.08	25.52	17.02	9.90	33.63
1-3 Million	Northeast	18.61	9.92	31.44	20.51	9.17	27.97	14.89	7.68	32.34
	North Central	19.06	9.84	30.29	21.09	10.96	30.64	17.46	9.54	31.81
	South	20.52	11.28	31.88	21.03	10.20	29.98	17.86	9.19	29.95
	West	20.04	10.83	30.09	22.74	12.89	30.93	19.74	11.55	32.90
Greater than 3 Million	Northeast	23.66	11.32	28.34	25.60	12.09	27.95	20.11	9.10	26.50
	North Central	23.59	12.94	31.10	27.40	13.31	28.21	25.54	16.88	32.85
	South	20.36	10.70	30.27	22.99	11.47	29.09	21.53	12.85	33.07
	West	23.35	12.62	31.77	23.12	10.82	27.01	21.86	13.09	32.79

Appendix Table 4: NONSTOP WORKTRIPS: COMPARISONS BY REGION, MSA SIZE, TIME OF DAY, PRIVATE VEHICLES ONLY, 1990, COMMUTERS RESIDING OUTSIDE CENTRAL CITY

MSA Population Size Class	Census Region	AM Peak Distance (minutes)	AM Peak Duration (miles)	AM Peak Speed (mph)	PM Peak Distance (minutes)	PM Peak Duration (miles)	PM Peak Speed (mph)	Off Peak Distance (minutes)	Off Peak Duration (miles)	Off Peak Speed (mph)
Less than 250,000	Northeast	19.58	12.44	36.16	20.10	11.68	34.46	20.34	13.10	35.22
	North Central	17.74	10.85	35.38	19.88	10.79	30.91	21.14	12.84	36.75
	South	19.35	11.68	35.22	18.15	11.49	35.56	19.01	12.85	37.82
	West	21.00	13.04	32.27	26.41	20.00	37.76	22.15	14.85	36.25
250,000-499,000	Northeast	22.86	15.27	35.56	23.54	14.19	34.83	20.22	13.01	33.87
	North Central	17.96	10.91	34.31	20.28	13.98	36.54	18.43	11.86	35.09
	South	19.34	11.48	34.76	22.76	13.60	34.23	20.13	13.42	36.68
	West	13.17	7.83	33.16	17.91	10.91	35.59	16.86	9.34	32.18
500,000-999,000	Northeast	20.48	12.80	35.49	22.39	14.05	35.21	20.60	12.57	34.41
	North Central	22.94	14.50	37.60	22.74	13.06	33.24	18.97	11.94	36.29
	South	21.24	13.27	35.12	23.99	14.45	35.77	20.44	12.92	36.30
	West	20.67	10.74	30.16	19.38	9.38	28.64	26.43	18.77	40.01
1-3 Million	Northeast	21.12	12.51	33.13	22.26	12.16	30.95	21.22	12.68	33.37
	North Central	20.82	12.55	34.12	22.58	12.37	31.03	18.68	11.60	35.78
	South	21.72	12.51	33.56	21.31	11.12	30.67	22.22	13.96	34.36
	West	23.10	12.53	33.10	26.17	12.60	29.58	23.61	14.15	34.90
Greater than 3 Million	Northeast	23.57	13.35	31.48	25.44	13.52	29.83	20.88	12.14	32.47
	North Central	24.64	13.27	31.03	25.34	13.25	30.71	20.80	12.37	32.93
	South	26.78	13.68	32.22	28.53	14.65	31.45	22.05	12.54	32.10
	West	23.67	13.77	32.79	28.00	15.21	32.13	24.08	15.51	35.49

Appendix Table 5: NONSTOP WORKTRIPS: COMPARISONS BY REGION, MSA SIZE, TIME OF DAY, SOLO DRIVERS, PRIVATE VEHICLES ONLY, 1990, COMMUTERS RESIDING INSIDE CENTRAL CITY

MSA Population Size Class	Census Region	AM Peak Distance (minutes)	AM Peak Duration (miles)	AM Peak Speed (mph)	PM Peak Distance (minutes)	PM Peak Duration (miles)	PM Peak Speed (mph)	Off Peak Distance (minutes)	Off Peak Duration (miles)	Off Peak Speed (mph)
Less than 250,000	Northeast	17.50	9.50	31.51	17.95	9.29	33.45	11.96	5.93	27.43
	North Central	11.94	5.94	27.85	13.20	6.17	26.35	10.44	5.29	30.83
	South	15.95	8.75	31.41	18.85	12.34	34.94	14.89	9.00	32.20
	West	12.10	6.22	27.81	12.72	7.04	28.41	11.51	6.05	28.39
250,000-499,000	Northeast	13.94	6.54	26.99	14.94	7.67	28.48	14.89	6.95	26.26
	North Central	12.94	6.69	31.78	14.08	6.58	27.92	15.10	8.86	34.05
	South	15.63	8.21	29.74	17.19	8.87	30.53	12.54	7.37	34.65
	West	15.16	7.63	29.39	14.82	7.12	28.46	11.90	6.85	30.05
500,000-999,000	Northeast	14.93	7.65	26.99	11.76	5.03	24.78	16.41	9.56	31.09
	North Central	14.17	7.71	31.47	13.29	7.06	30.05	12.91	6.77	30.97
	South	18.78	11.12	33.11	20.09	10.57	30.32	16.52	9.79	34.23
	West	18.08	7.00	24.38	18.14	6.90	24.28	16.69	9.91	34.00
1-3 Million	Northeast	17.41	10.04	33.36	19.09	8.91	30.11	15.02	7.95	32.99
	North Central	19.11	10.15	30.95	21.34	11.33	31.36	17.32	9.74	32.44
	South	20.61	11.27	31.60	20.97	10.02	29.36	18.98	9.75	29.82
	West	20.77	11.31	30.64	23.13	13.00	30.60	20.99	12.34	33.01
Greater than 3 Million	Northeast	24.68	11.93	28.32	25.66	12.41	28.15	20.34	9.66	27.63
	North Central	24.12	13.62	32.23	28.12	13.83	28.96	20.92	10.62	28.97
	South	20.74	11.09	30.81	23.25	11.71	29.33	19.91	11.80	32.37
	West	23.47	12.56	32.68	23.22	10.90	27.71	21.89	13.24	32.89

Appendix Table 6: NONSTOP WORKTRIPS: COMPARISONS BY REGION, MSA SIZE, TIME OF DAY, SOLO DRIVERS, PRIVATE VEHICLES ONLY, 1990, COMMUTERS RESIDING OUTSIDE CENTRAL CITY

MSA Population Size Class	Census Region	AM Peak Distance (minutes)	AM Peak Duration (miles)	AM Peak Speed (mph)	PM Peak Distance (minutes)	PM Peak Duration (miles)	PM Peak Speed (mph)	Off Peak Distance (minutes)	Off Peak Duration (miles)	Off Peak Speed (mph)
Less than 250,000	Northeast	19.59	12.20	35.54	20.64	11.92	34.03	21.89	13.86	33.89
	North Central	17.75	10.84	35.89	20.56	11.70	33.55	20.94	13.26	38.76
	South	18.99	11.51	35.45	18.50	11.88	36.13	18.88	12.58	37.04
	West	23.05	14.62	32.98	22.43	16.21	36.67	22.98	15.19	35.07
250,000-499,000	Northeast	21.13	13.11	34.57	24.26	14.85	35.25	19.53	12.39	33.78
	North Central	17.95	11.15	34.99	20.18	13.96	36.55	18.41	12.15	35.96
	South	19.81	11.69	34.92	22.42	12.92	33.67	20.56	13.86	37.24
	West	13.37	8.27	35.28	16.53	10.11	35.98	17.45	9.74	33.23
500,000-999,000	Northeast	20.58	13.01	35.47	22.66	14.01	34.82	20.45	12.61	35.02
	North Central	23.82	14.84	36.31	23.87	13.58	32.16	19.23	12.20	36.81
	South	20.97	12.89	35.04	22.91	14.33	36.70	20.34	12.89	36.76
	West	19.67	10.52	28.82	20.50	10.20	29.69	25.50	18.77	39.47
1-3 Million	Northeast	21.66	12.97	33.41	23.11	12.72	30.88	21.35	12.87	33.69
	North Central	20.31	12.25	34.10	22.36	12.31	31.05	18.47	11.51	35.38
	South	21.80	12.68	33.72	21.69	11.44	30.95	20.27	12.54	34.33
	West	21.26	11.83	32.79	24.95	11.75	28.87	22.39	14.11	34.89
Greater than 3 Million	Northeast	22.90	12.88	31.22	24.30	13.06	29.64	20.35	11.87	32.36
	North Central	24.53	13.09	30.94	25.54	13.45	30.97	19.90	11.94	33.44
	South	26.90	13.85	32.64	28.39	14.78	32.00	21.73	12.93	33.09
	West	22.75	13.34	33.07	27.58	15.12	32.35	23.77	15.24	35.39

Appendix Table 7: PER CAPITA ANNUAL PERSON-TRIPS BY MEN, BY MODE AND PURPOSE, 1983 AND 1990 NPTS

Purpose	Private 1983	Private 1990	Public 1983	Public 1990	Other[a] 1983	Other[a] 1990	Total 1983	Total 1990	Percent Change
Earning a living	236.38	237.82	9.43	9.52	25.86	12.54	271.68	259.87	-4.35
Family & personal business	269.20	353.55	3.59	3.06	47.41	24.95	320.20	381.56	19.16
Civic, educational & religious	59.44	66.10	4.70	3.91	46.07	44.35	110.20	114.36	3.77
Social & recreational	215.10	228.48	5.05	3.13	58.99	33.87	279.14	265.48	-4.89
All purposes[b]	798.45	892.00	22.71	19.85	182.05	117.10	1003.20	1028.95	2.57

Notes: [a] Includes trips by bicycle, walking, school bus, taxi, airplane, Amtrak, moped and other modes.
[b] Category "Other trips" not shown.

Source: Travel Day data, Patricia S. Hu and Jennifer Young, 1992, *Summary of Travel Trends: 1990 Nationwide Personal Transportation Survey.* Conversations with the authors indicate that 1983 data are estimates currently being revised.

Appendix Table 8: PER CAPITA ANNUAL PERSON-TRIPS BY WOMEN, BY MODE AND PURPOSE, 1983 AND 1990 NPTS

Purpose	Private 1983	Private 1990	Public 1983	Public 1990	Other[a] 1983	Other[a] 1990	Total 1983	Total 1990	Percent Change
Earning a living	154.32	175.24	10.60	8.09	11.99	9.63	176.91	192.96	9.07
Family & personal business	339.16	444.89	4.04	5.25	29.46	30.17	372.66	480.31	28.89
Civic, educational & religious	69.29	80.02	6.10	5.02	44.90	37.29	120.30	122.32	1.68
Social & recreational	223.00	217.64	3.63	3.07	34.54	30.81	261.17	251.53	-3.69
All purposes[b]	805.06	924.11	24.78	21.49	124.17	109.07	954.00	1054.67	10.55

Notes: [a] Includes trips by bicycle, walking, school bus, taxi, airplane, Amtrak, moped and other modes.
[b] Category "Other trips" not shown.

Source: Travel Day data, Patricia S. Hu and Jennifer Young, 1992, *Summary of Travel Trends: 1990 Nationwide Personal Transportation Survey.* Conversations with the authors indicate that 1983 data are estimates currently being revised.

The Demography of the U.S. Vehicle Fleet: Observations From the NPTS

Alan E. Pisarski

The Demography of the U.S. Vehicle Fleet

Outline

The Demography of the U.S. Vehicle Fleet

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Executive Summary

One of the important trends observed in the NPTS data has been the increasing share of vehicle miles of travel generated by the older vehicle fleet. This is a product of two factors: the increasing proportion of the fleet that consists of older vehicles; and the increasing travel activity of these older vehicles. This study uses NPTS data as the fundamental source to examine the characteristics of the vehicle fleet specifically in terms of age, identify the characteristics of the owners of the vehicles in the aging fleet, and describe the ways in which those vehicles are used.

Parallelling our aging human population is the aging population of vehicles in our national auto fleet. The demography of the aging vehicle fleet is a subject that has not been carefully examined by transportation analysts. It is a dramatic and important story.

In 1969, the age of the vehicle fleet (back then the minuscule number of personal pickups and vans were not counted) was 5.1 years. By 1977 it had increased to an average age of 5.6 years, by 1983 it was 7.6 and by 1990 it was 7.7 years. (After 1977 the NPTS differentiated vans and pickups from autos showing that they tended to be slightly older than autos.)

A number of the points made in the report are summarized here.

- Total travel growth has been substantial, almost all of it coming from older vehicles.
- Growth in the size of the vehicle fleet has come not so much from expanded sales but from declines in scrappage of vehicles as they age.
- Total travel by vehicles two years of age or under has increased only slightly in absolute terms and therefore has sharply diminished as a share of total travel.
- In 1969 vehicles two years of age or under accounted for 42 percent of total travel, declining to a current level of 22 percent.
- Almost half, 48 percent, of current travel is generated by vehicles of six years of age or greater, whereas in 1969 only a quarter of travel came from such vehicles.
- VMT by the four age groups has grown to be roughly equal in shares in the range of 500-600 billion VMT each.
- Vehicles ten years old or greater now generate as many miles of travel as do vehicles two years and under (22 percent).
- The black and hispanic populations own older vehicles than the average for the nation. The differences in age diminish with increasing household vehicle ownership.
- Older cars tend to be used more for work travel than the average for all vehicles.
- Women tend to use newer cars than men.
- Travel purposes where new vehicles tend to predominate are work connected business travel and social-recreational travel.
- The Pacific and Mountain regions have a larger share of older vehicles than their share of all vehicles.
- Rural areas and small metro areas tend to have a disproportionate share of old vehicles.
- Large numbers of older vehicles in the central cities of western states could have substantial impacts on air quality.

The implications of the aging of the fleet are profound and can only be sketched here. Further, more detailed work needs to be done. The characteristics of the aging fleet and its use tell us a great deal about the mobility of our population.

Its most significant point in terms of public policy impact is the lag in penetration of the vehicle fleet of future innovations in areas such as fuel efficiency, pollution generation, and safety.

The fuel consumption characteristics of this older fleet clearly lag that of the newer fleet. The pollution control characteristics are probably even more pronounced. National focus is crucial. Analysis of ways to really make progress against the air pollution characteristics of transportation may well determine that this is a central problem to be addressed.

In terms of safety there are so many new safety features—anti-lock brakes, airbags, traction control, etc. that will only slowly gain share of the fleet—that the implications for accidents, injuries and deaths is almost frightening. Its importance for the ability to generate IVHS related changes in the fleet will be of major concern.

I. The U.S. Vehicle Fleet

In 1990 the resident population of the United States was about 240 million, according to the NPTS; also in 1990 the vehicle fleet population in use by that human population was in excess of 165 million. Such a large population, of people or vehicles, has its own special nature and characteristics. Little has been done to effectively explore the characteristics of the vehicle population. If we are going to peaceably coexist with that vehicle population we need to know more about it—specifically where it has been historically, where it is now, and where the trends indicate that it is tending.

Long term patterns of growth are presented in Figure I.1, which shows the indexed growth rates of the nation's human population, households, workers, drivers, and vehicle population.[1] The variables charted clearly differentiate themselves into three clusters. The first cluster consists of only one variable, the national population growth trend. It has grown slowly in the period, increasing by slightly more than 21 percent over the 21 year period of observation. The second cluster consists of three variables all growing at roughly the same rate of between 48 and 58 percent over the period. This group includes household growth, worker growth and licensed driver growth: note that licensed drivers increased at almost three times the rate of growth of the general population. The third cluster, vehicular growth, grew at an extraordinary rate of over 125 percent: six times the rate of population, and twice the rate of growth of the number of drivers.

Considered in absolute terms the growth in vehicles has been similarly substantial. Table I.1 shows that total vehicles increased by over 90 million while the total population only added about 40 million persons in the period of observation. The scale of the increases is revealing. In descending order they are:

Vehicles	92 million
Drivers	60 million
Workers	42 million
Population	42 million
Households	30 million

[1] Vehicles will be used as a term throughout this discussion as defined in the NPTS; that is vehicles are motorized vehicles, including automobiles, vans, pickup trucks and other light vehicles used for personal transportation. When it is intended to separately treat autos or trucks they will be specifically identified. In 1969, before the boom in pickup truck use for personal needs, the NPTS survey did not include pickup trucks.

Figure I.1:
DEMOGRAPHIC GROWTH TRENDS: 1969 = 100, 1969-1990

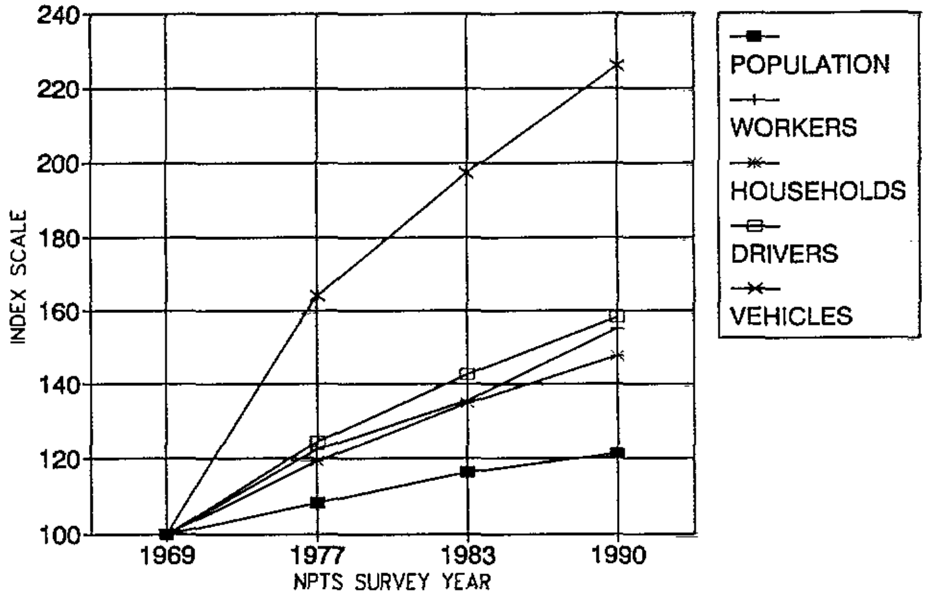


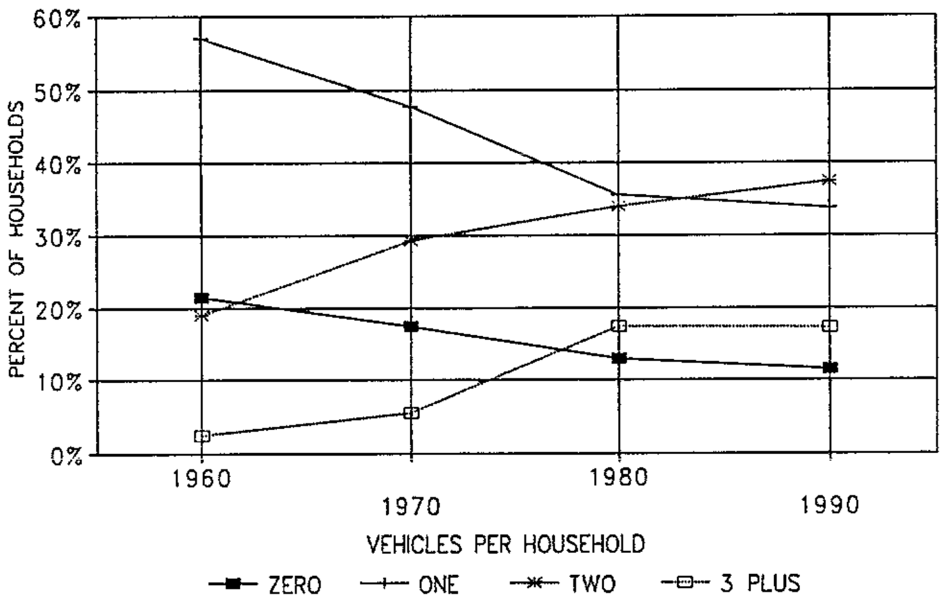
Table I.1: BASIC DEMOGRAPHIC MEASURES (IN MILLIONS)

	Pop.	Workers	Households	Drivers	Vehicles
1969	197	76	63	103	73
1977	213	93	75	128	120
1983	229	103	85	147	144
1990	239	118	93	163	165

However, as prodigious as these numbers are, there are signs of a slowing in the fleet's expansion. If one considers the levels of change it is most striking in annual terms. From 1969 to 1977 the annual increase in the size of the vehicle fleet was almost exactly 6 million vehicles, from 1977 to 1983 it dropped to 4 million vehicles per year and from 1983 to 1990 it reached a level of 3 million new vehicles per year added to the fleet. The current level of growth is about 1.8 percent per year which places the U.S. well behind most of the other nations in the world in annual vehicle growth rate.

Figure I.2 makes a further point regarding the trends in vehicle growth. It depicts the shares of households by vehicle ownership groupings. These data are generated from the decennial census and differ somewhat from the NPTS values. They suggest that there seems to be a stabilizing of percentages of households by vehicle ownership level. The significant shifts in shares of households by vehicle ownership seems to have ended in the 1980 to 1990 period, most notably the historically dramatic increases in shares of households with three or more vehicles actually reversed. This is further supported by the trends in NPTS data regarding vehicles per household which show that the big increases were achieved in the 1969-1977 period and have remained relatively stable since then. From 1969 to 1977 vehicles per household jumped from 1.16 to 1.59, but have increased to only 1.77 since.

Figure I.2: HOUSEHOLDS BY VEHICLES AVAILABLE TRENDS 1960-1990



Aging Characteristics of the Fleet

The key point about the development of the vehicle fleet is that it is not particularly the product of a boom in annual vehicle sales. Figure I.3 shows the annual sales of vehicles in the United States, both domestic and foreign-made, from 1976 to 1990. While there has been growth in total annual sales it has not been dramatic. After the declines in the early eighties, a product of recession, sales have exhibited no particular growth pattern. Total annual sales have been higher after the recession than before, but not dramatically so: annual vehicle sales have moved in a range between 14 and 15 million vehicles per year, picking up the trend from 1978. The most significant change has been the increase in light truck sales in the post-1982 period.

Figures I.4 and I.5 compare the 1980 and 1990 sales and retirements statistics for autos and trucks. Figure 4 shows that both births and deaths of autos were slightly greater in 1990 compared to 1980 with the net effect of slightly fewer autos added to the fleet in 1990 than in 1980. The data for trucks show a much greater difference in sales and retirements than in autos. Overall, the year 1990 added almost 2.5 million vehicles in net terms to the fleet, over 2 million of which were trucks. Figure I.6 summarizes these points.

What these data suggest is that, in large part due to trucks, the net retention of vehicles has increased over the years. A study by the Oak Ridge National Laboratory[2] demonstrates this effectively. Figures I.7 and I.8, show the survival rates for both autos and trucks. It is evident from the charts that historically trucks have had a tendency to last longer than autos. The trends indicate that the probability of survival of older vehicles has increased for both autos and trucks over the three time periods studied. For example, in the 1966-73 period a 15-year-old auto had a survival rate of less than 10 percent and by the 1978-89 period that probability had increased to more than 25 percent. A 15-year-old truck had a probability of survival of 44 percent in the 1966-73 period rising to almost 54 percent. So the auto fleet has improved in survival more than trucks but still lags behind trucks considerably.

This has meant that the average age of the vehicle fleet has increased from slightly above 5 years in 1969 to almost 8 years by 1990. Table I.2 provides the detailed data for average ages of the auto and truck fleets. As shown in the table, the average age for automobiles has climbed steadily over the years. The average for trucks has been more erratic, actually dropping from 1983 to 1990. This could be primarily attributable to the dramatic increases in light truck sales since the 1982 recession for use as personal vehicles.

[2] Study of Vehicle Scrappage Rates, Miaou, Shaw-Pin, 1990

Figure I.3:
VEHICLE FLEET SALES BY YEAR DOMESTIC AND IMPORTS 1976-1990

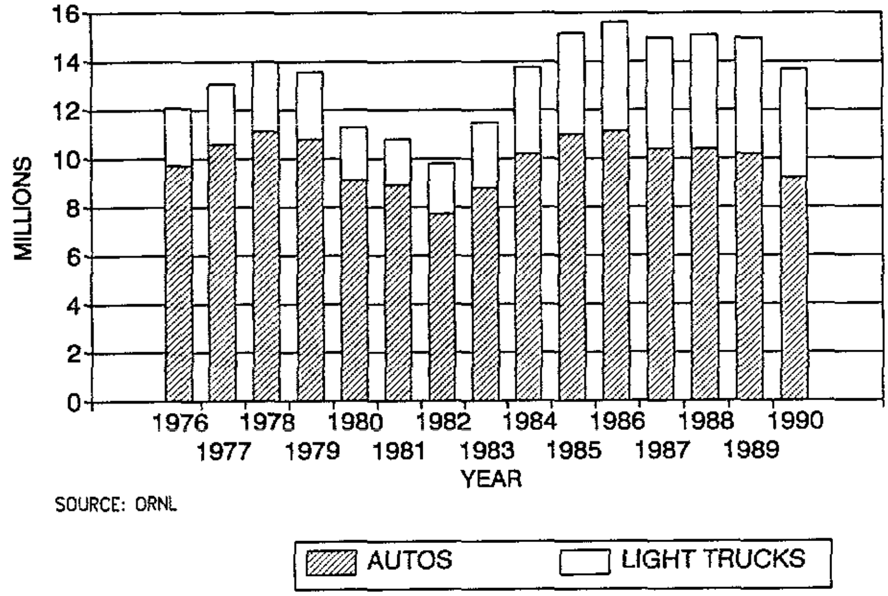


Figure I.4:
AUTO SALES AND RETIREMENTS 1980-1990 COMPARED

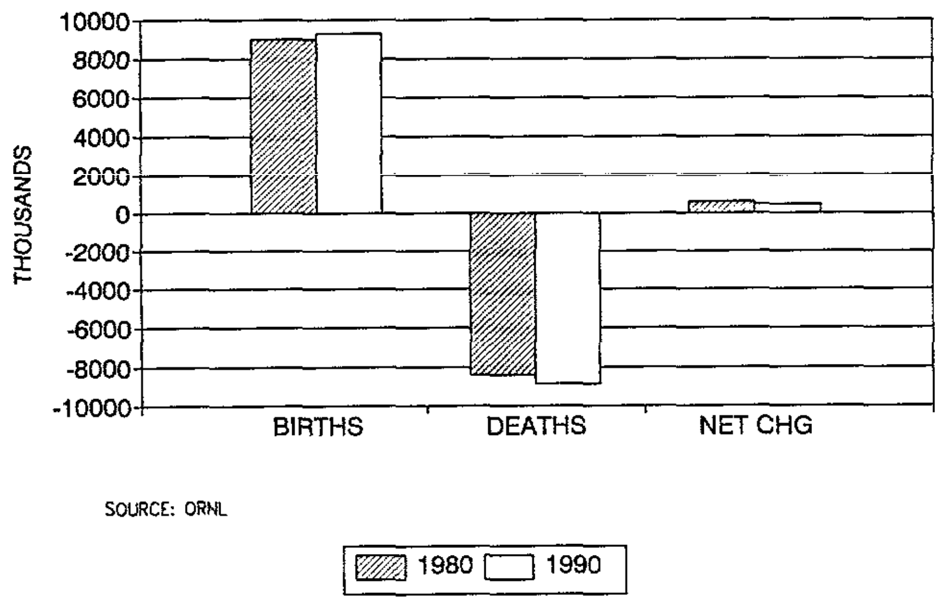


Figure I.5:
TRUCK SALES AND RETIREMENTS 1980-1990 COMPARED

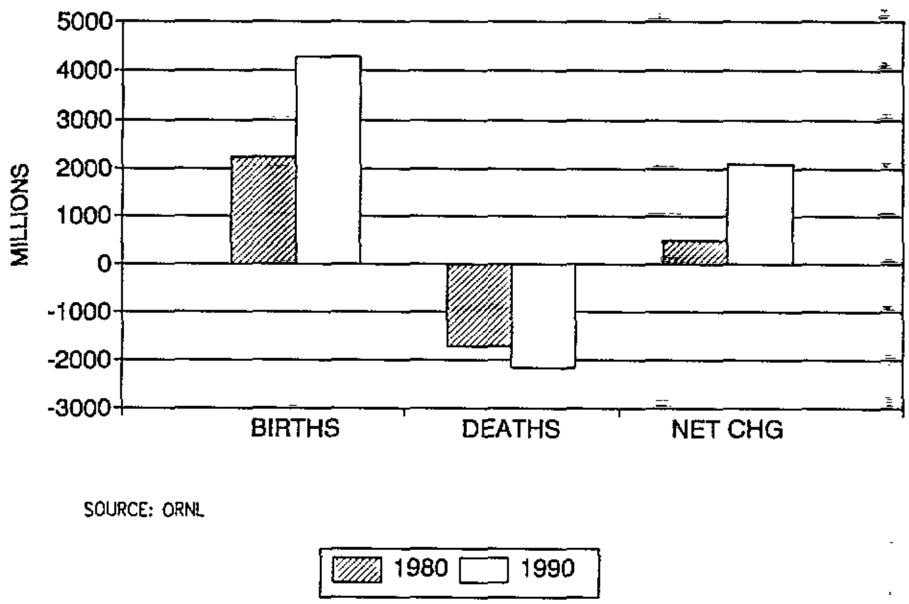
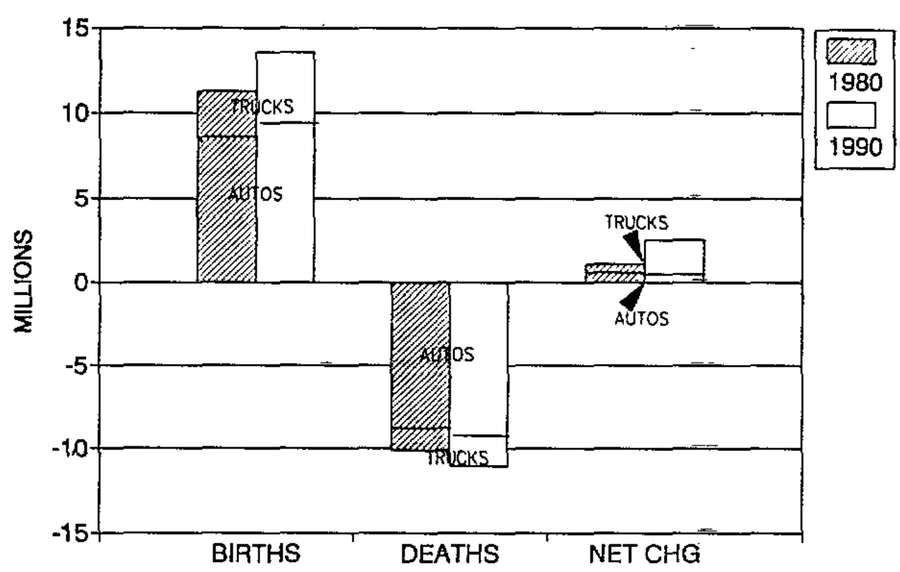
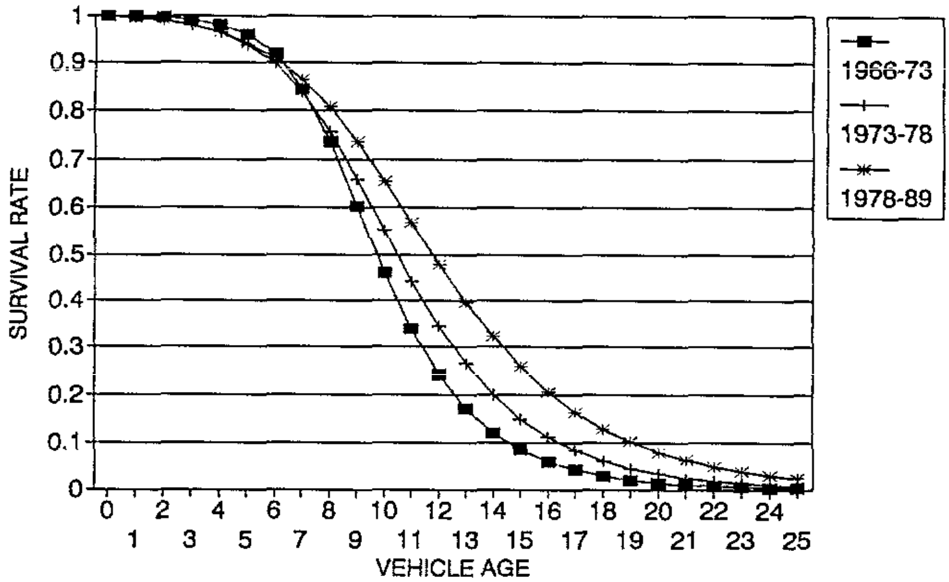


Figure I.6:
VEHICLE SALES AND RETIREMENTS 1980-1990 COMPARED



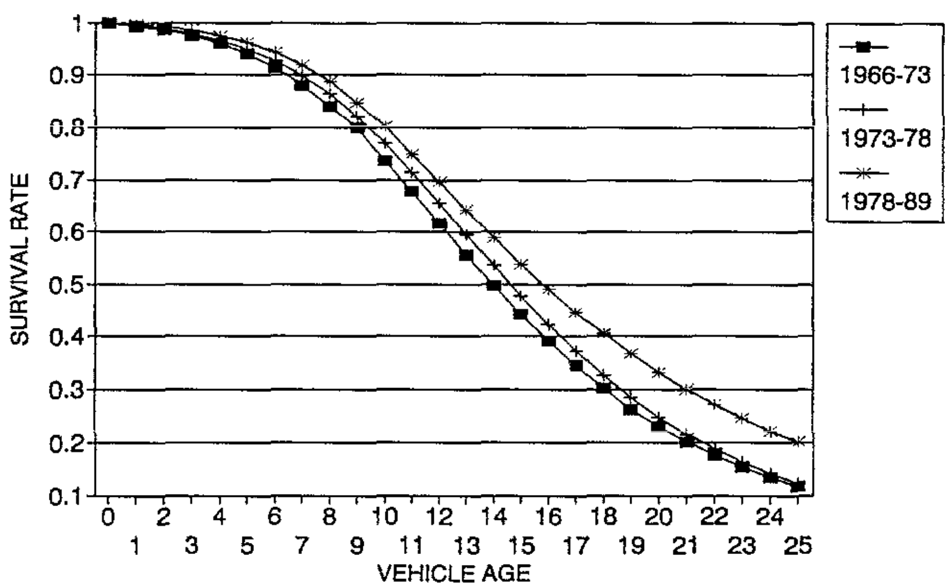
SOURCE: STAT. ABS.

Figure I.7:
VEHICLE SURVIVAL RATES FOR AUTOMOBILES 1966-1989



SOURCE: HWY STATISTICS; FHWA

Figure I.8:
VEHICLE SURVIVAL RATES FOR TRUCKS 1966-1989



SOURCE: HWY STATISTICS; FHWA

Table I.2: VEHICLE AVERAGE AGE TRENDS

Vehicle	1969	1977	1983	1990
Auto	5.1	5.5	7.2	7.6
Truck	—	6.4	8.8	8.0
All	5.1	5.6	7.6	7.7

These averages were the product of changing distributions of the fleet by age group. Notable in this distributional change is the decline in the share of the new fleet up to two years of age. It declined from almost 32 percent of the fleet in 1969 to less than 17 percent in 1990. At the same time the share of the fleet ten or more years old had the reverse pattern increasing its share from roughly 11 percent to over 30 percent.

More detailed information on the growth of the fleet by age appears in Figure I.9. This very graphically illustrates that the number of vehicles under two years of age has remained roughly the same for over twenty years. Thus the total increase in the fleet is almost exclusively a product of the increase in older vehicles, and the increases in vehicles in the fleet of more than 10 years of age is most pronounced. Viewed in terms of total vehicles we see an interesting story unfold. All of the fleet increases have occurred in the older age categories, most notably the over ten year fleet. The 3-5 year fleet about doubled, the 6-9 year fleet almost tripled, and the ten and over fleet increased more than 6 times.

This is most emphatically depicted by Figure I.10 which shows the net change in total vehicles by age group between the 1969 and 1990 surveys of the NPTS. The number of vehicles 10 years of age or more in the fleet has jumped by more than 40 million vehicles, almost half of the total increase in vehicles in the period. Clearly the U.S. population has increased their ownership of vehicles not so much by adding new vehicles but by not throwing the old ones away. The figures suggests a story of the U.S. population buying vehicles at a roughly constant rate but then not discarding them with age. The comparisons of sales with scrappage and survival rates confirm this.

Figure I.11 shows the age distribution of the vehicle fleet in percentage terms for the four NPTS survey years. Most significant in the depiction are the variations in the distribution for vehicles of 10 years of age and over. The decline in percentage terms of the first year of sales is also pronounced. The pattern throughout the central elements in the distribution is a little less clear.

Useful corroboration of the NPTS data for 1990 is provided by the ORNL presentation of R.L.Polk data from registrations, *reproduced by permission here.* As can be seen from Figure I.12, the registration data and NPTS survey data are almost identical—the significant area of difference, not unexpectedly, is in the number of vehicles of one year of age or less.

This is a picture with both positives and negatives. The good news is that the fleet is lasting longer. The typical vehicle today can last ten years or more, which was almost unheard of in the sixties. This has positive implications for the recycling needs of the vehicle fleet. On the negative side it suggests that the ability for innovations to permeate the fleet is increasingly difficult. There are important safety, fuel efficiency and pollution control innovations becoming part of the fleet every year. These will enter the main stream only very slowly.

Figure I.9:
SIZE OF THE VEHICLE FLEET BY AGE GROUP 1969-1990

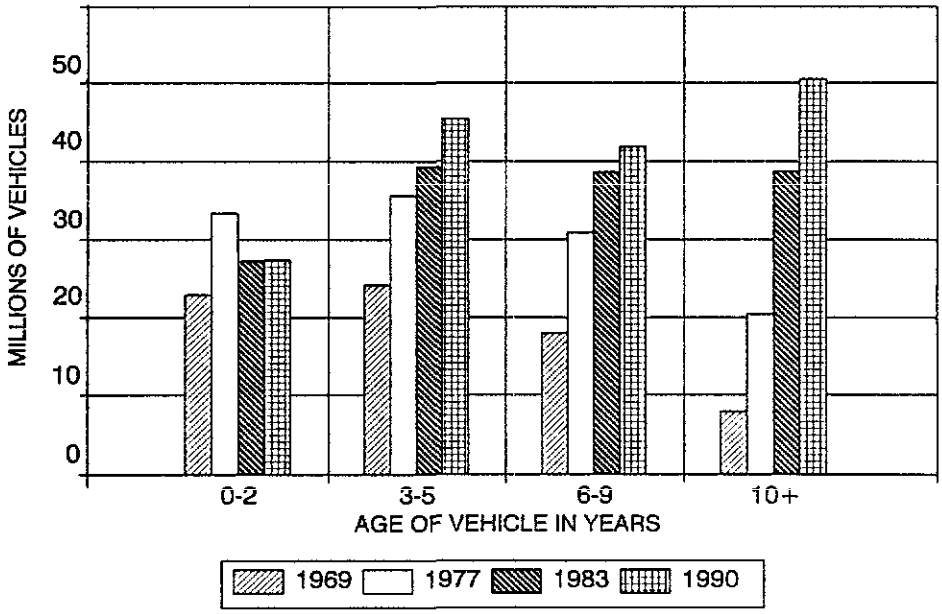


Figure I.10:
NET INCREASE IN THE VEHICLE FLEET BY VEHICLE AGE 1969-1990

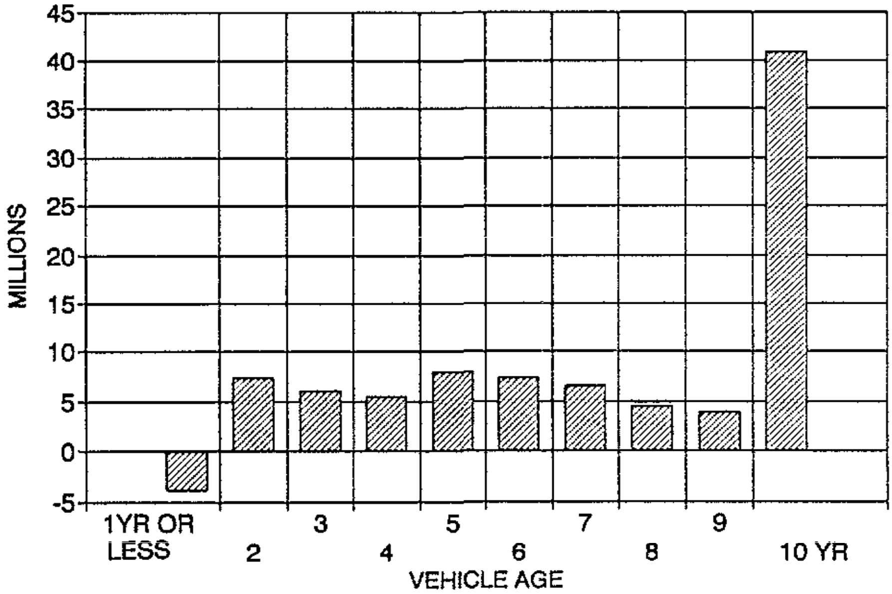


Figure I.11:
PERCENT DISTRIBUTION OF THE VEHICLE FLEET BY AGE: 1969-1990

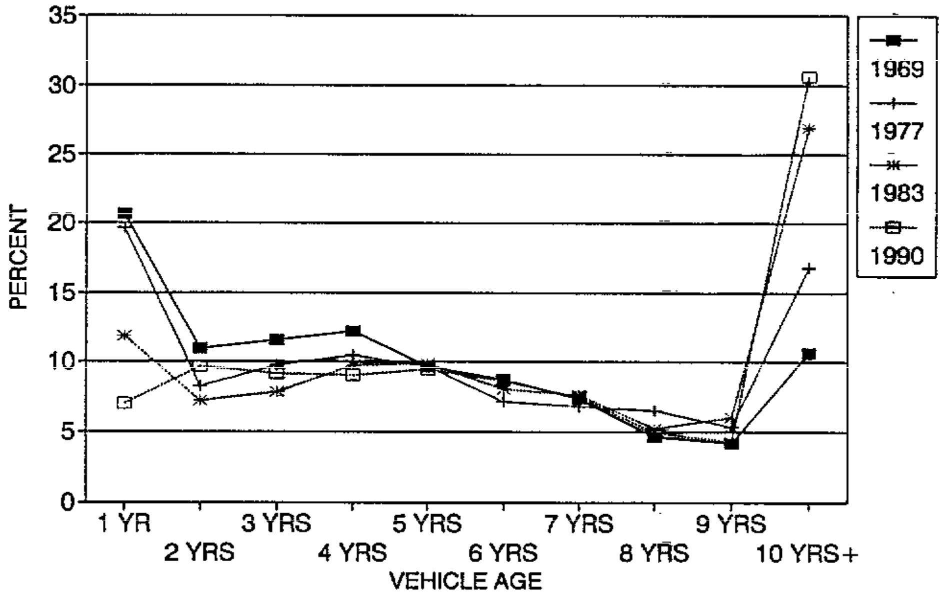
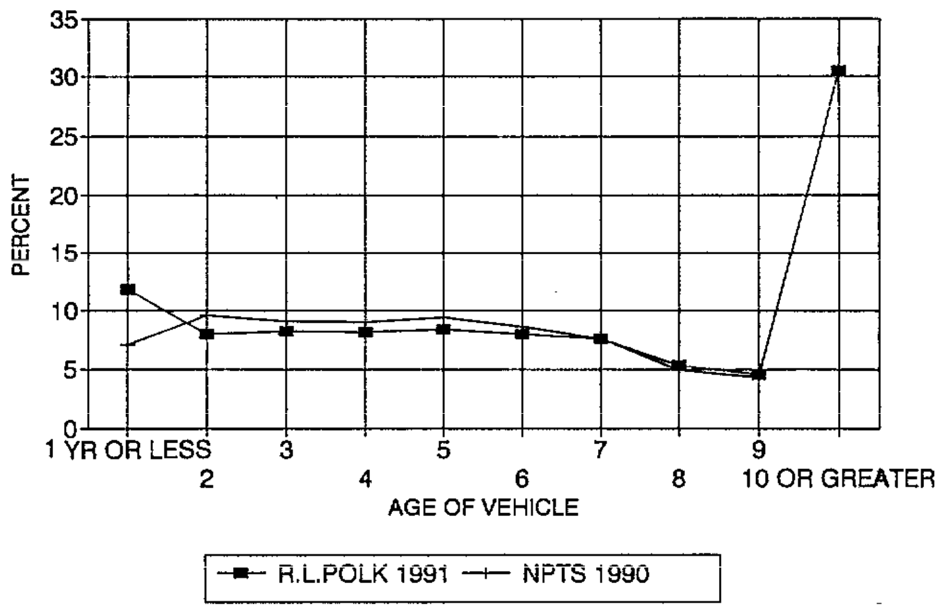


Figure I.12:
AGE DISTRIBUTION OF THE VEHICLE FLEET FROM TWO SOURCES



II. Who Owns the Older Vehicle Fleet?

All of this must be evaluated in the context of increasing vehicle availability per capita. The demographic characteristics of the population using these older vehicles—their age, sex, income and locational characteristics—is an important story. Trip purposes and time of day factors could also be crucial. The NPTS provides an amazingly rich resource to better understand the undercurrents in these trends.

Distribution by Race

There appears to be a tendency for different racial and ethnic cohorts to have different vehicle ownership characteristics with respect to age. These differences are not dramatic. The data cited here are based on the race or hispanic status of the head of household. Overall, the ownership of the auto fleet is differentially distributed by race and ethnicity with the non-hispanic white population owning a greater share of the fleet than blacks or hispanics. This is consistent with stage in the life cycle, income and locational factors that govern ownership. The white non-hispanic population, with 73 percent of the population, owns 82 percent of the vehicles; the black population, with 12 percent of the population, has 9 percent of the fleet; and the hispanic population, with 9 percent of the population, has 6 percent of the fleet. Table II.1 shows that ownership distribution within vehicle age group.

TABLE II.1: RACE AND ETHNICITY AND THE VEHICLE FLEET

Race/Ethnicity	% Pop 1990 Census	% Households With Vehicles	Vehicles in HH	%Vehs	%Vehs >10 Yrs Old
White, Non-Hispanic	72.7	82.1	1.92	83.6	—
Black	12.1	9.1	1.29	7.8	—
Hispanic	9.0	6.0	N.A.	5.7	—
Other	7.6	2.8	N.A.	2.8	—

Figure II.1 depicts the average age of vehicles owned for non-hispanic whites, blacks, and hispanics, by number of vehicles in the household. In one-vehicle households the average of vehicles for white non-hispanic households is less than 6.5 years, rising to over 7 for black households, and about 7.5 years for hispanics. The patterns shown suggest that as the number of vehicles increases in the household the differences in average household fleet age between the racial and ethnic groups decline. This would seem to be consistent with what one would expect based on the relationships of income levels of households and vehicle ownership. For example, at the three vehicle ownership level the differences in age of the household fleet between black and white households is inconsequential. At the four vehicle and above level (where sample sizes are very limited) both black and hispanic household fleet ages are newer than that of the white population.

Distribution by Sex

It is not always feasible to establish the specific age of vehicles stratified by the sex of the owner. In households where there is only one vehicle all household members with licenses will use it; similarly, where there are multiple vehicles and multiple licenses there will be cross-over use of vehicles. Where the principal user is identified there is a slight indication that females tend to have the use of newer vehicles than males. For male drivers, 16.3 percent of them are the principal driver of a vehicle of two years of age or newer, compared to 16.9 percent for female drivers, a slight difference. The difference is more accentuated by looking at the distribution of the fleet of seven years or greater. About half of male drivers, 51.4 percent, are the principal drivers of vehicles seven years of age or greater, whereas only 41.2 percent of women are. This is accentuated by the differential ownership of trucks by males which tend to be older.

Of the 10.8 million trucks 7 years of age or older, 9.6 million have males as the principal driver. Table II.2 summarizes some of the basic statistics by vehicle type. The percentages shown relate to the shares of the fleet held by the principal drivers.

Figure II.1: AVERAGE AGE OF VEHICLES IN HOUSEHOLDS BY NUMBER OF VEHICLES AND RACE OF HEAD

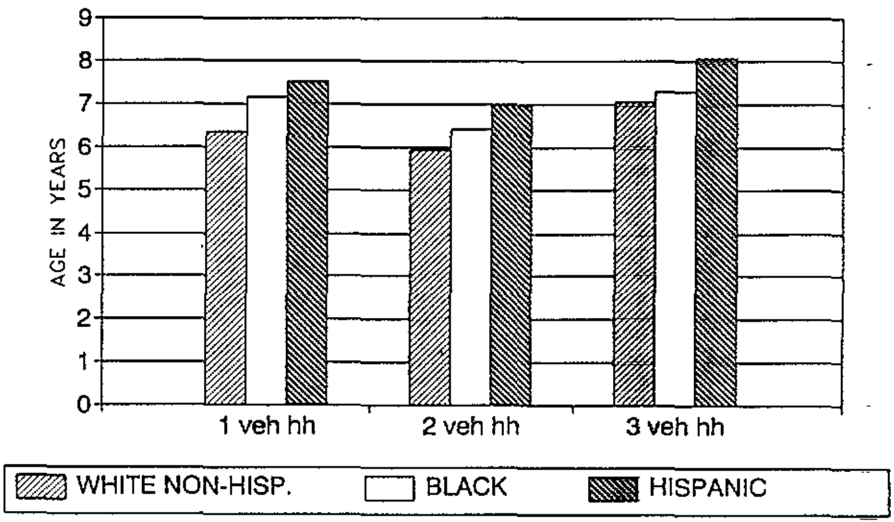
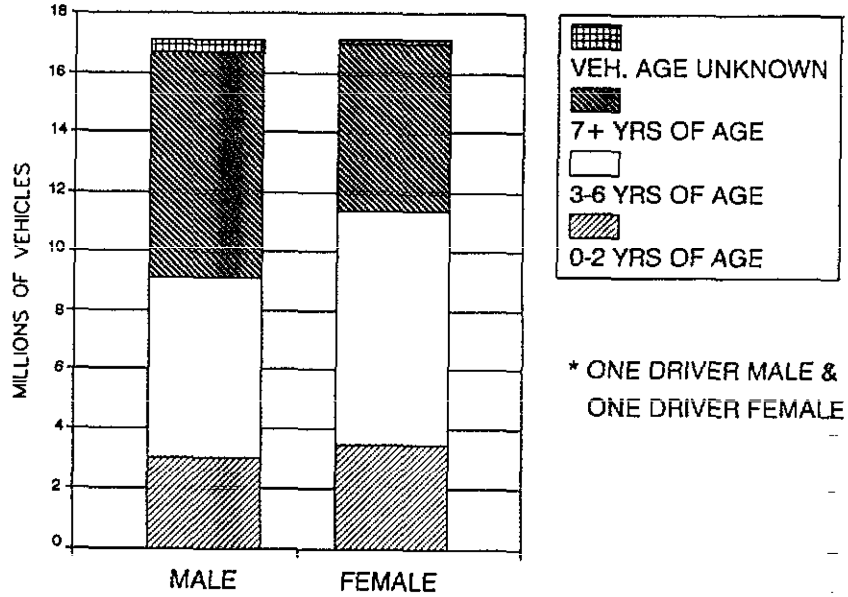


TABLE II.2: VEHICLE AGE AND SEX CHARACTERISTICS (VEHICLES IN THOUSANDS)

Vehicle Age		Male	Female	Total
0-2	Auto–Van	7,093	9,645	16,740
	Pickup	3,489	433	3,922
	Total	10,713	10,097	20,852
	%	(51.4)	(48.6)	(100)
3-6	Auto–Van	14,844	23,483	38,330
	Pickup	6,111	1,152	7,264
	Total	21,170	24,645	45,819
	%	(46.2)	(53.8)	(100)
7+	Auto–Van	23,294	23,882	47,180
	Pickup	9,599	1,189	10,788
	Total	33,716	25,134	58,854
	%	(57.3)	(42.7)	(100)
All Vehicles		68,943	60,879	129,842
		(53.1)	(46.9)	(100)

The NPTS Databook looks at a specific and interesting case. Table 3.33 of the Databook examines the age distribution of vehicles in households with exactly two drivers, one female, one male, and exactly two cars. The data are distributed based on knowledge of who is the principal driver of each vehicle. Based on these data it appears clear that women tend to have access to the newer vehicles in such households; the average age of vehicles used by men was 7.23 years while that of women was 5.85 years. Figure II.2 provides greater detail on this pattern. It shows that 20 percent of women use vehicles of two years of age or newer while only 17.5 percent of men do; and almost 45 percent of men use vehicles over seven years of age, while only 33 percent of women do. Among the factors that may affect this pattern would be that males tend to use non-automobile vehicles more than women and these vehicles tend to be slightly older than autos. But a more significant supposition, only anecdotal in its data support, is that because women would tend to drive children more, and because new cars tend to be safer, they would more likely use the safer, and therefore newer car. This seems to be supported by the growing safety consciousness among young parents, borne out by sales trends. This also seems borne out by the trip purpose patterns discussed later in this report.

Figure II.2:
AGE OF VEHICLES BY SEX OF DRIVER FOR 2 VEHICLE / 2 DRIVER HOUSEHOLDS*



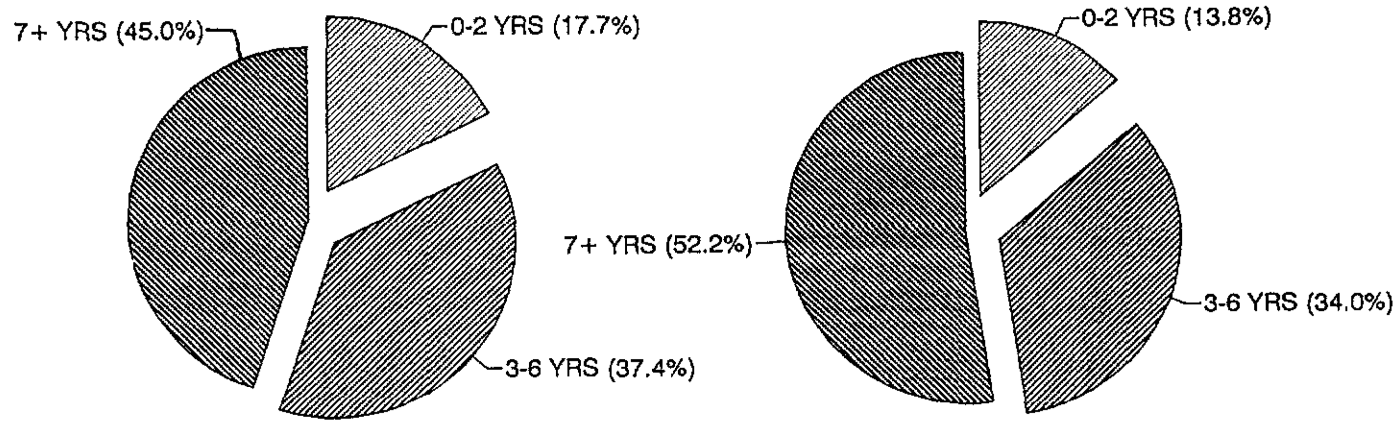
* ONE DRIVER MALE & ONE DRIVER FEMALE

Distribution by Employment Status

As expected, those that are employed tend to have newer vehicles than those not employed. Interestingly, the numbers are greater than the male/female differences discussed above. About 17.7 percent of those employed, full or part-time, have a vehicle of two years of age or newer, while those not employed have about 13.8 percent of their vehicles in the same age group. This is a difference of 3.9 percentage points, contrasted to a .6 percent difference between females vs males. Figure II.3 further depicts some of these data.

It must be recognized that these data compare the vehicle's principal user by employed or not employed status, which is very different than unemployed status. The not-employed would include the retired, who can be quite wealthy, and also would include the spouses of the employed, whose labor force status is other than employed.

Figure II.3:
DISTRIBUTION OF VEHICLES BY AGE



PRINCIPAL DRIVER: EMPLOYED **PRINCIPAL DRIVER: NOT EMPLOYED**

Distribution by Income

Unlike most countries, low income households in the United States are substantial owners of vehicles. The average auto ownership rates for households by income class are shown in Table II.3. Households below $10,000 in income still average one vehicle per household.

Table II.3: VEHICLE OWNERSHIP BY INCOME GROUP

Income Class (000'S)	Number of Households	Average Vehicle Ownership
Under $10,000	9,252	1.0
$10,000-19,999	13,011	1.4
$20,000-29,999	12,294	1.7
$30,000-39,999	11,323	2.0
$40,000 Plus	21,704	2.3
All Incomes	93,347	1.8

Not surprisingly lower income households tend to own and use older vehicles. Figure II.4 shows the total VMT generated by each income group in vehicles of differing age. The figure shows that while the share of travel produced by older vehicles among the higher income groups is small, the total amount is still greater than that produced by the lower income groups. A perhaps more effective way to visualize the relationship between income and vehicle age is presented in Figure II.5 containing cumulative levels of travel (VMT) by age of vehicle for the extreme low and high categories of income available in the NPTS and for all income groups. As shown in the figure, low income drivers produce a large share of their travel in old vehicles, e.g. about 50 percent of all vehicular travel by those whose incomes are below $10,000 occurs in vehicles older than 1981, whereas for the high income group that percentage is not reached until between the 1985 and 1986 vintages.

Another factor related to income, shown in Figure II.6, is that lower income groups tend to travel fewer miles per year. The figure shows that, for instance, over half of travel per vehicle by the lowest income group is less than 7,500 miles per year. In contrast, the higher income group produces only 30 percent of its travel at less than 7,500 miles per year per vehicle. This linkage of lower travel levels and older vehicles is one in which cause and effect is not clear. Poor quality vehicles may inhibit travel by lower income groups.

Figure II.4:
VMT BY VEHICLE AGE BY INCOME CLASS

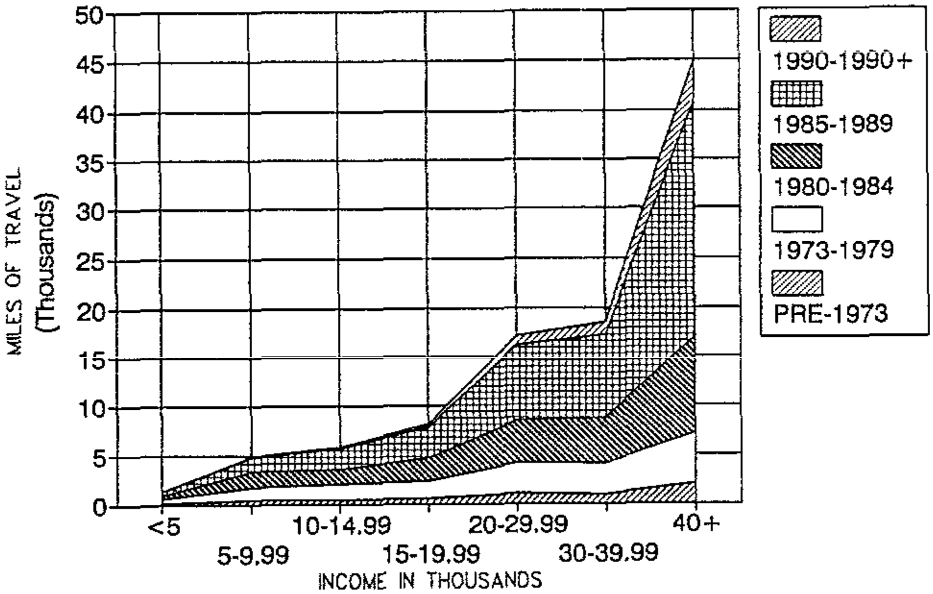


Figure II.5:
SHARES OF TRAVEL BY AGE OF VEHICLE FOR SELECTED INCOME GROUPS

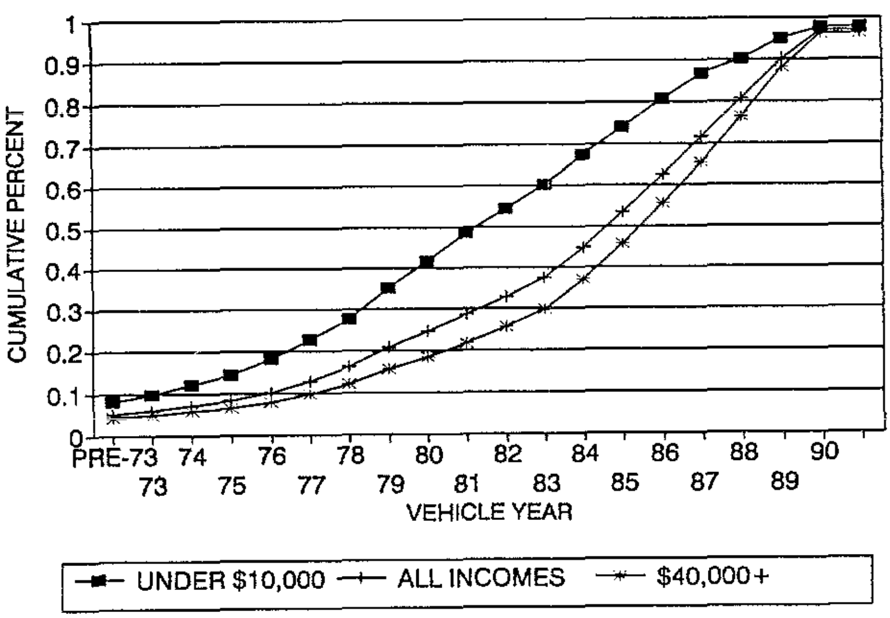
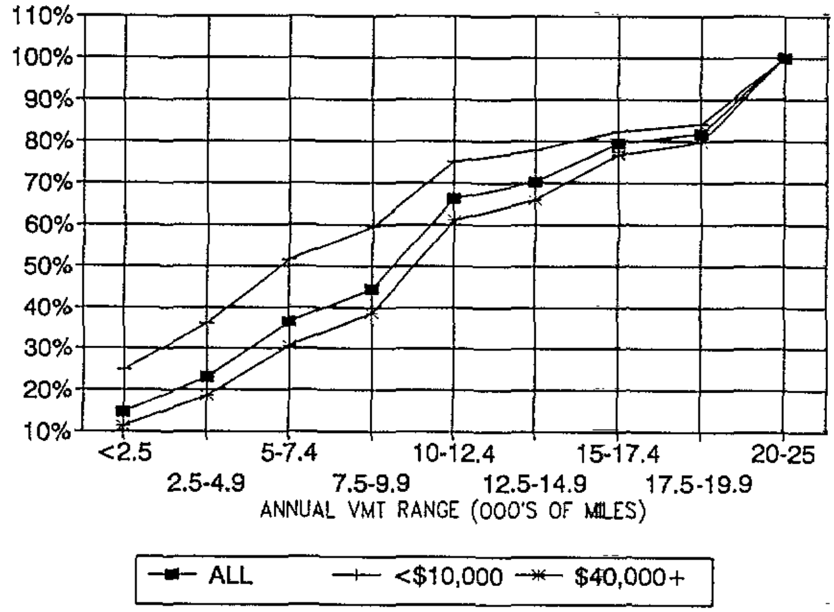


Figure II.6:
CUMULATIVE % VMT BY VMT PER VEHICLE FOR SELECTED INCOME CLASSES



III. Geographic Distribution of the Fleet

Distribution by Region

Like the population the automobile fleet has been migrating toward the South and the West. We know that like the population the vehicle fleet is not distributed uniformly across the nation. This leads to the question of whether the distribution by age of vehicle follows the general pattern for all vehicles. Figure III.1 presents the distribution of the total fleet by four age groupings. Figure III.2 a map of the Census Region boundaries is provided for reference. The most significant aspect of this distribution is that there are some surprises with respect to the distribution of the older fleet. In the nation overall about 25 percent of vehicles are pre-1981. Most regions are close to that percentage, but there are several outliers. In the East, both the New England and Mid-Atlantic regions have significantly less than average shares of the older fleet—New England has less than 14 percent of its fleet in the pre-1981 age group, while the Middle Atlantic is closer to 20 percent.

Three regions have over 30 percent of their fleet in the pre-1981 group. The West North Central region has about 31 percent. This may be a product of two factors; this area is heavy in three vehicle households and would be expected therefore to have older third and fourth cars. Also, this is an area that is heavily oriented to pick-up trucks which tend to be older than passenger autos. The other regions with notable age bias in vehicles are the Mountain (33%) and Pacific (32%), A factor worth noting is that this is the area where dry hot conditions tend to minimize rust and corrosion and may contribute to vehicle longevity. The substantial shift of the national population to these regions may be a factor in the aging of the fleet in that a larger share of the national population is living in areas today that are not as hostile to vehicles as in the past. Overall, the Mountain and Pacific states with 22 percent of the nation's vehicles have more than 28 percent of the vehicles that are pre-1981.

The shares that each region has of the national set of pre-1981 vehicles are shown in Figure III.3. Because these vehicles are likely to be implicated in air quality issues, it is important to know where these vehicles are with respect to urban areas. The data indicate that these vehicles are differentially distributed with respect to urbanized status. In the West North Central region about 25 percent of all vehicles are inside the central city of an urbanized area but only 21 percent of pre-1981 vehicles are located there. And while areas outside the metro areas of the region held 58 percent of vehicles, they accounted for 67 percent of the pre-1981 fleet. The Mountain and Pacific states show a similar pattern with a greater share of pre-1981 vehicles in the rural areas, but with an overall smaller share of vehicles in rural areas in general. Table III.1 shows the percentage distribution of vehicles within Census Region by metropolitan area status.

Figure III.1:
DISTRIBUTION OF THE VEHICLE FLEET BY CENSUS REGION AND AGE OF VEHICLE

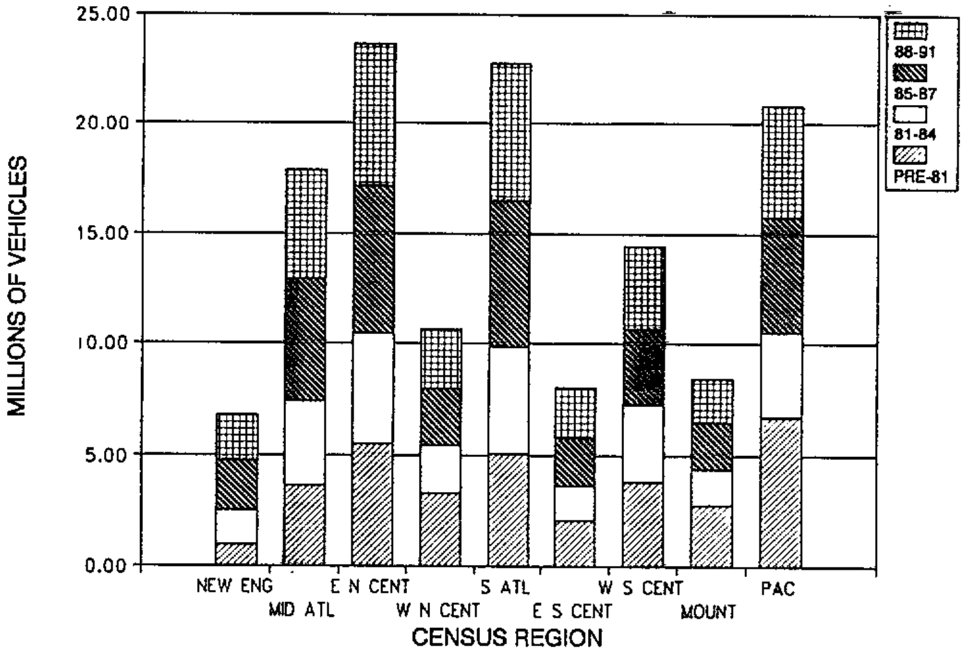


Figure III.2:
CENSUS REGIONS AND DIVISIONS OF THE UNITED STATES

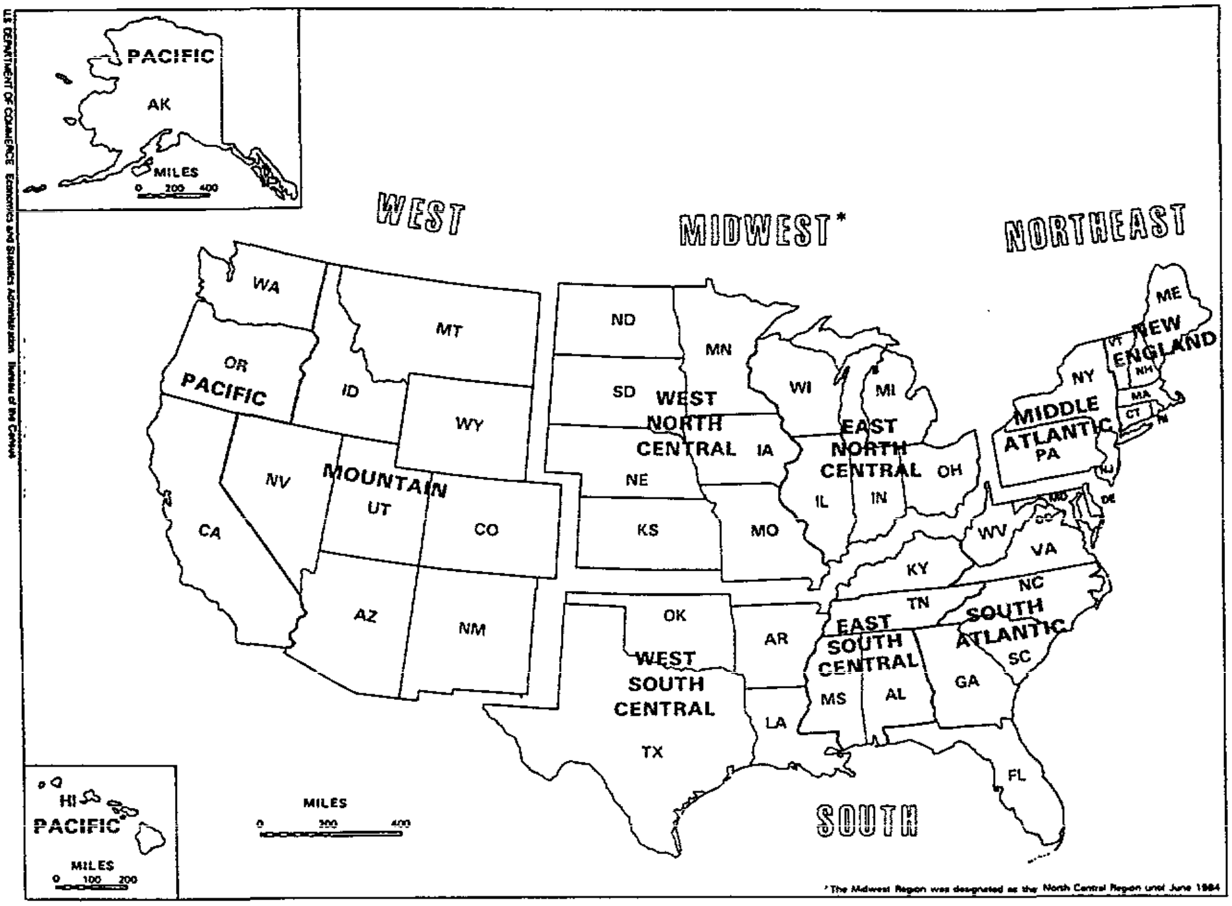


Figure III.3:
DISTRIBUTION OF PRE-1981 VEHICLES BY CENSUS REGION

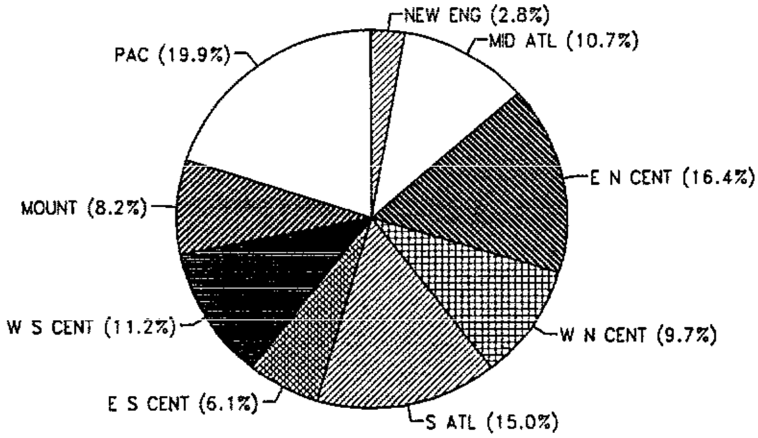


Table III.1: DISTRIBUTION OF PRE-1981 VEHICLES BY METRO STATUS

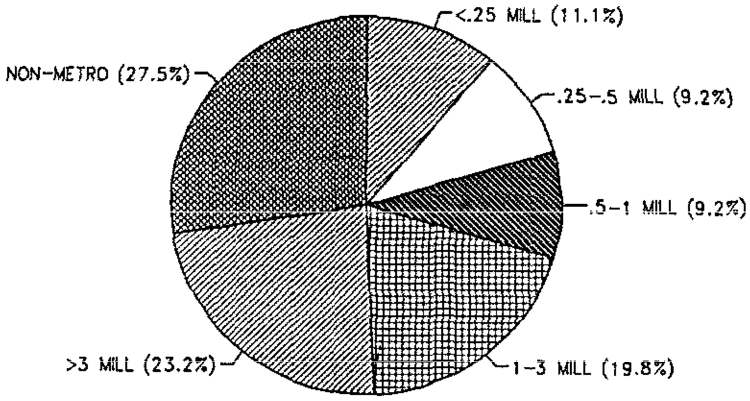
Region	Percent in MSA Central City	Percent in MSA; Not in Central City	Not in MSA
New England	25.0	31.8	43.1
Middle Atlantic	26.5	43.3	30.3
East North Central	32.2	21.0	46.8
West North Central	21.2	11.6	67.2
South Atlantic	26.9	24.4	48.7
East South Central	22.2	8.2	69.6
West South Central	45.6	11.4	43.0
Mountain	40.7	14.9	44.4
Pacific	38.1	33.7	28.2
Total	32.3	23.5	44.3

The average annual vehicle miles of travel for pre-1981 vehicles in these areas do not seem to indicate any remarkable characteristics to differentiate them from the national average. Of course these vehicles tend to be operated for fewer miles per year than the average for all vehicles, as expected. In many regions the central city vehicles traveled more than the suburban or rural vehicles, possibly due to being the single household vehicle in central cities where vehicle ownership is lower. This is supported by analysis by metro area size which indicates that the heaviest use of old vehicles is in the largest metro areas over 3 million where annual miles of about 9600 are indicated contrasted to ranges around 8600 miles in the smaller metro areas. When mileages are compared by area size, without stratification by age, mileages are uniform across size strata at about 12,500 miles per vehicle.

Distribution by Metro Area Size

The distribution of pre-1981 vehicles by metro area size is shown in Figure III. 4. It indicates that in total numbers most of the vehicles are in non-metro areas and in areas over 3 million. If each metro area size group is compared to the national average of about 25 percent of all vehicles are represented by those pre-1981 in age, there are several notable variations from the national average. Most significantly the locations with the highest proportions of pre-1981 vehicles are in the smallest metro areas, those below 250,000 and in non-metro areas. Small metro areas have 28 percent old vehicles and non-metro areas have 29 percent. The largest metro areas have the smallest proportion of old vehicles with less than 20 percent pre-1981 vehicles in the over 3 million population group.

Figure III.4:
DISTRIBUTION OF PRE-1981 VEHICLES BY METRO AREA SIZE



IV. Vehicle Travel

Further making the point of the expanding quality of the fleet is the fact that that fleet is not just around but it is being used. If the older fleet was just being retained by the population, with low levels of attendant use, that would be a matter of only anecdotal interest, but it appears that that is not the case. It is a well known attribute of vehicle travel that new vehicles tend to be used more than older vehicles. This characteristic continues, but it continues in an overall pattern of increasing travel by all vehicles, independent of age. This is most notable in the 1983-1990 period and is particularly pronounced among the older fleet. Figure IV.1 captures that pattern for age groups most clearly. Its primary characteristic is that the disparity between annual travel levels by vehicle age is diminishing. While the new fleet of 2 years or less increased in VMT per vehicle by 7 percent between 1969 and 1990, the percentage increases in VMT increased in each age group up to a 41 percent increase in the VMT of the fleet over 10 years of age. Figure IV.2 provides greater detail showing VMT per year for individual years of vehicle age. As is shown in the figure the 1990 annual travel measures for vehicles in each age group has almost uniformly increased from the values for earlier periods. Figure IV.3 from the Residential Transportation Energy Consumption (RTEC) survey performed by the Energy Information Agency of the DOE provides further support to the general pattern observed in the NPTS. RTEC basically covers the intervals in the period between the 1983 and 1990 NPTS observations.

Examining the component elements of the vehicle miles of travel data for 1990 in more detail provides further understanding. It appears that the trips made per vehicle decline slowly with vehicle age, most notably after the seventh year. More significantly, average trip length also declines with vehicle age, and declines more substantially than does the trip rate. After the fifth year of age trip length has significantly diverged from the norm. Figure IV.4 depicts these patterns using an index with the first year as 100. Total vmt/vehicle, of course, also declines following the trip and trip length patterns.[3]

Again, R.L. Polk data provide corroboration of these observations. Figure IV.5 compares the NPTS VMT distribution by age to that observed in the 1991 R.L. Polk data set.

Greater understanding of the nature of the travel generated by vehicle age group can be obtained by looking at the distributions of travel by annual mileage range for each vehicle age group. These data are difficult to depict. Figure IV.6a, b, and c shows the percentage distribution of travel by annual mileage range for three vehicle ages—pre-1963 vehicles (i.e. 17 years old at the time of the 1990 survey), 1980 vehicles (10 years old) and 1990 vehicles. The key point made in this graphic is that the average mileage per year of older vehicles tends to fall in a low range, e.g. almost 50 percent of the vehicles of a vintage earlier than 1963 traveled less than 2,500 miles per year. Alternatively, the new vehicles, the 1990s, had only about five percent of their vehicles with such little mileage (see IV.6c), whereas over 25 percent of them traveled in excess of 20,000 miles per year. As expected the 1980 vehicles held the central position between the two extremes of new and old. These data also illustrate the classic lumpiness of mileage estimates clustering around the five and ten thousand mile values.

[3] VMT/vehicle as used here is the product of trips/vehicle and average trip length.

Figure IV.1:
VEHICLE MILES OF TRAVEL PER VEHICLE BY AGE GROUP 1969-1990

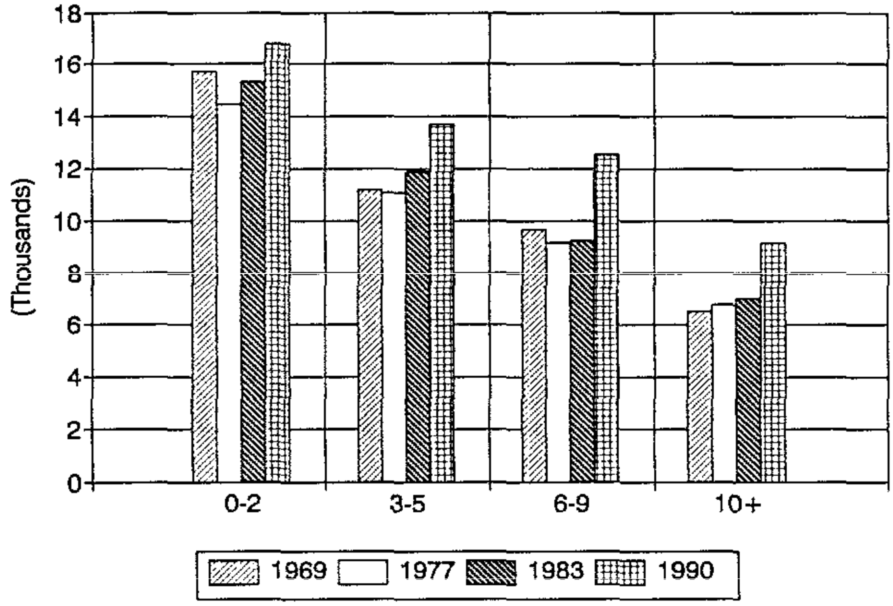


Figure IV.2:
ANNUAL VMT PER VEHICLE BY VEHICLE AGE FOR NPTS SURVEY YEARS

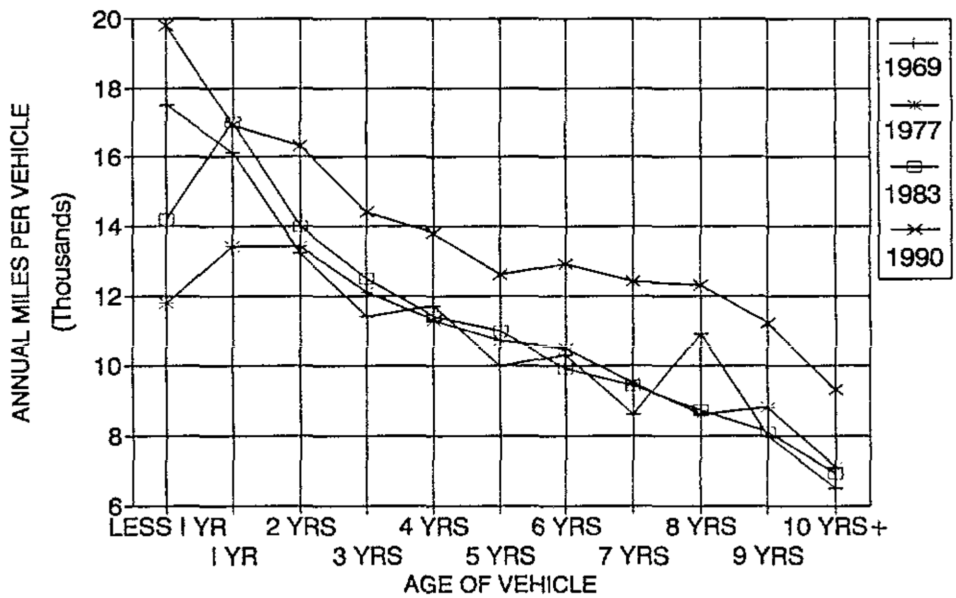
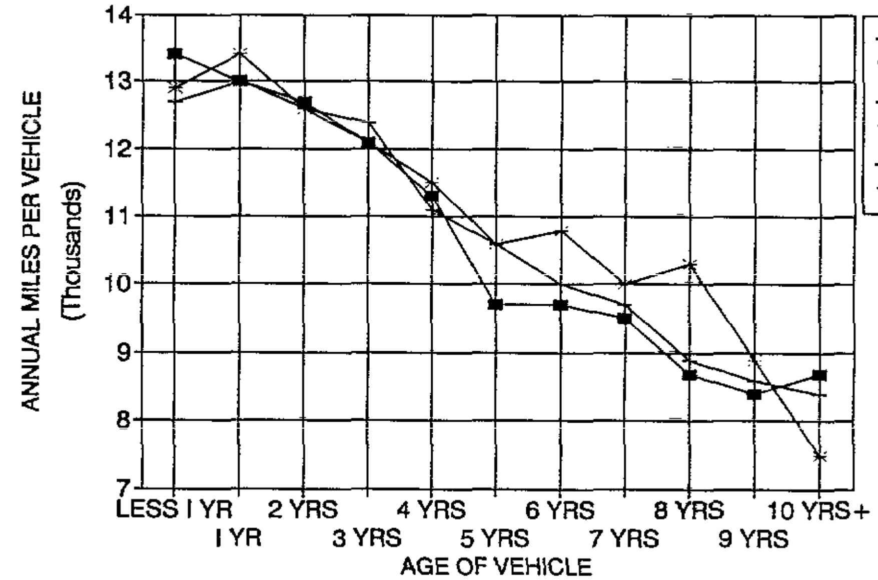


Figure IV.3:
ANNUAL VMT PER VEHICLE BY VEHICLE AGE FOR RTECS* SURVEY YEARS



Res. Trans. Energy Consum. Survey; EIA

Figure IV.4:
SUMMARY STATISTICS BY VEHICLE AGE GROUP 1990

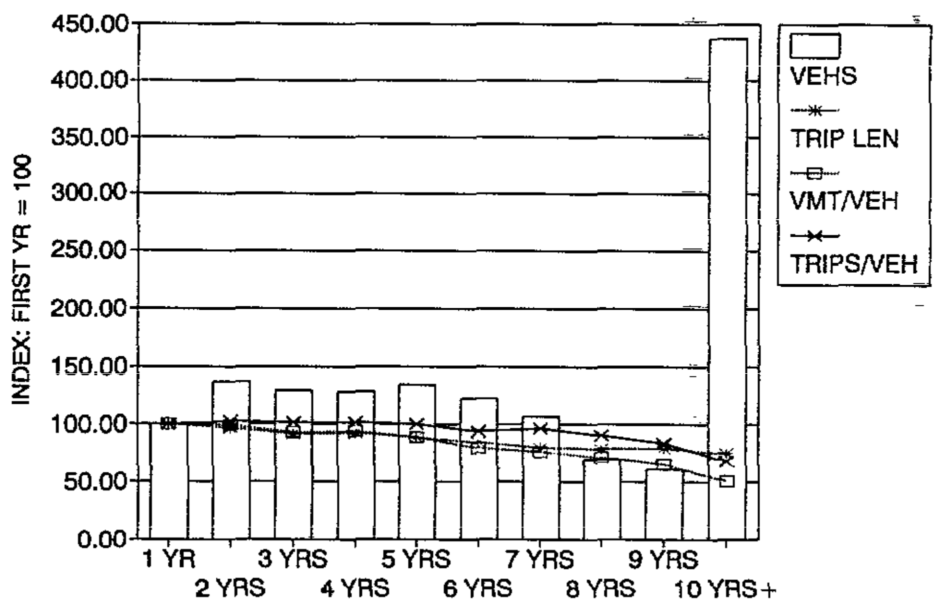


Figure IV.5:
VMT DISTRIBUTION OF THE VEHICLE FLEET FROM TWO SOURCES

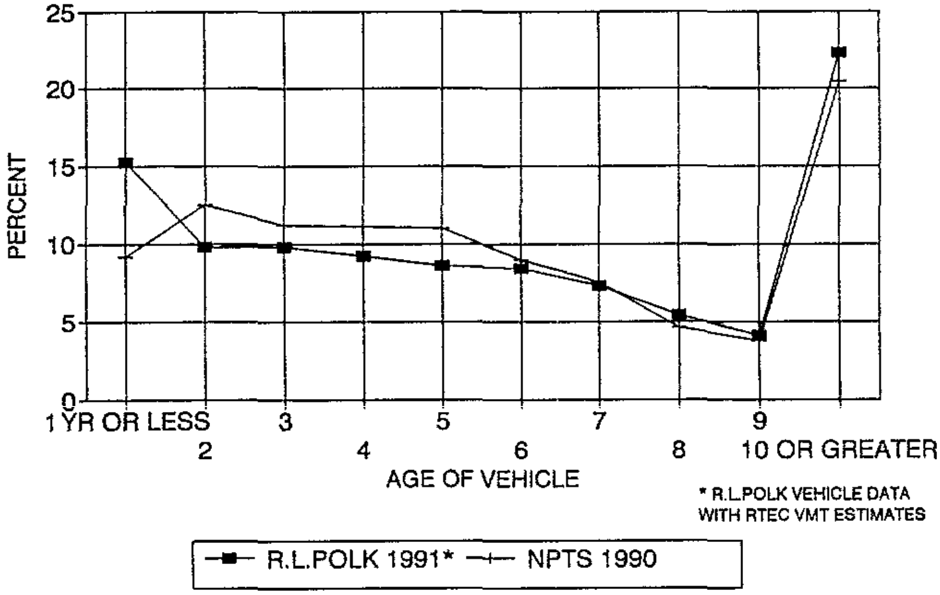


Figure IV.6a:
% VEHICLES BY ANNUAL MILES TRAVELED BY AGE OF VEHICLE

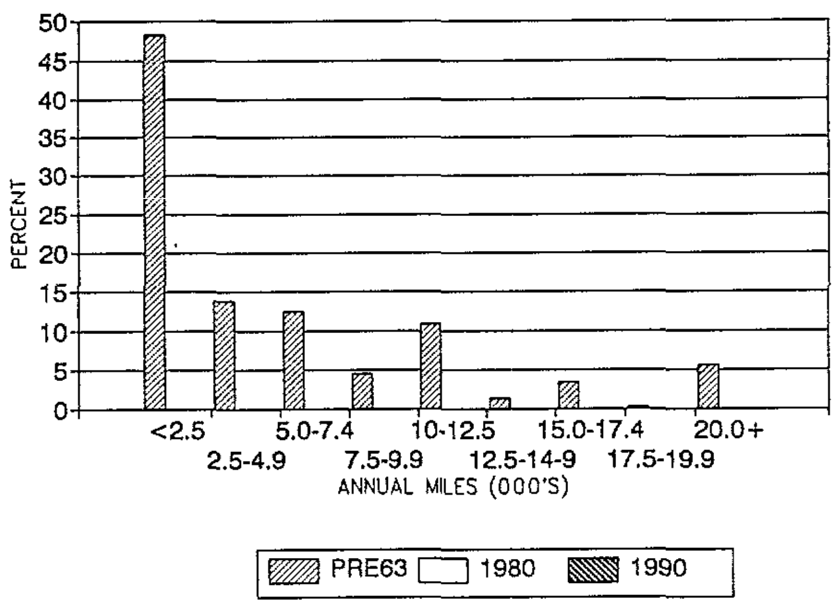


Figure IV.6b:
% VEHICLES BY ANNUAL MILES TRAVELED BY AGE OF VEHICLE

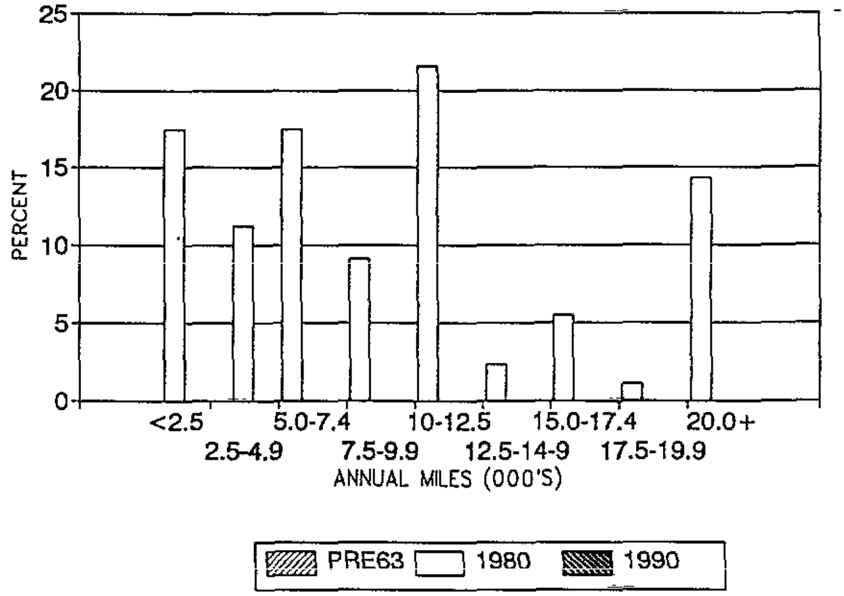
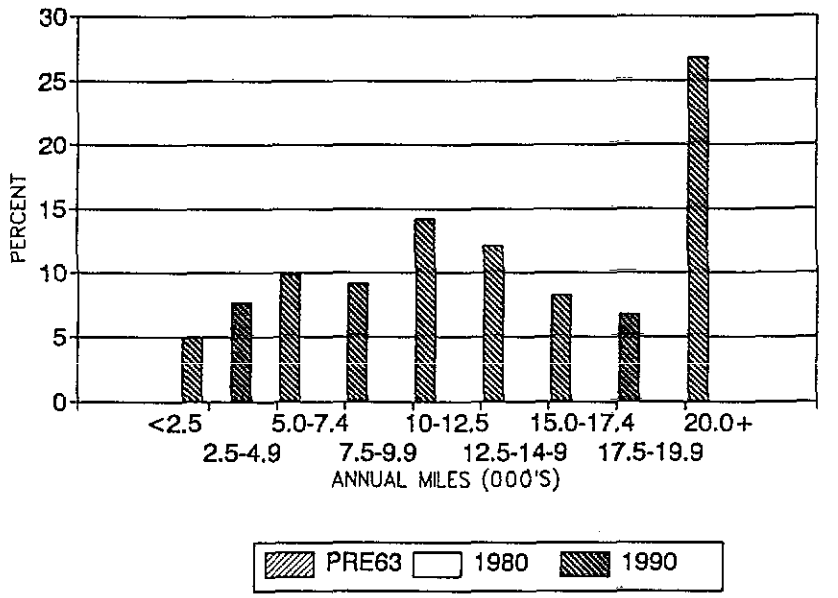


Figure IV.6c:
% VEHICLES BY ANNUAL MILES TRAVELED BY AGE OF VEHICLE



The question remaining is what shares of total travel are being generated by different vehicle age groups. Figure IV.7 goes a long way toward answering that question. A number of points are made by this chart:

- total travel growth has been substantial, almost all of it coming from older vehicles;
- total travel by vehicles two years of age or under has increased only slightly in absolute terms and therefore has sharply diminished as a share of total travel;
- in 1969 vehicles two years of age or under accounted for 42 percent of total travel, declining to a current level of 22 percent;
- almost half, 48 percent, of current travel is generated by vehicles of six years of age or greater, whereas in 1969 only a quarter of travel came from such vehicles;
- VMT by the four age groups has grown to be roughly equal in shares in the range of 500-600 billion VMT each;
- vehicles ten years old or greater now generate as many miles of travel as do vehicles two years and under (22 percent).

Distribution by Purpose

The discussion above indicates that there are changes in trip rates and trip lengths as vehicles age. A factor that could affect this would be the tendency for vehicles of certain ages to be used for selective purposes rather than general use. There are other questions as well that better understanding of the purpose-related travel of vehicles by age can answer. We have noted the tendency for women to use newer vehicles; is this purpose related? We are very interested in the safety, fuel efficiency and pollution consequences of older vehicles; how is this affected by purpose relationships?

One way to examine the patterns is to look at the VMT distributions by purpose of each vehicle age group and determine the extent to which there are any patterns that are discernible. The overall distribution of VMT by purpose of travel for all vehicles, independent of age, is shown in Figure IV.8. Comparison to this distribution by each vehicle age group indicates that pattern differences are not dramatic, but that there are some purpose categories where a tendency toward purpose specialization can be noted. Care must be exercised because looking at minor purpose categories by vehicle age category can stretch the NPTS sample beyond its capabilities. The trip purpose categories that show no special leanings in regard to vehicle age include: trips for shopping, family business, school/church, and visit Doctor/Dentist purposes. All of these tend to be intuitively acceptable. One of the key patterns of interest is the work trip pattern, which show a tendency for a greater share of the travel activity of older vehicles to be used for work than the average. This is depicted in Figure IV.9, in which the share of a vehicle's use for work, for each vehicle age group, is plotted against the average share for all vehicle age groups. For example, 1991 vehicles have about a half percent less share of their travel oriented to work travel than do all vehicles without respect to age. All of the vehicles with shares greater than the average of 21.6 percent are vehicles older than 1983. Other patterns that show more distinctive tendencies by age are: work-related business purposes, which tend to have higher shares among newer cars; and social-recreational purposes which also are shifted toward newer vehicles.

Figure IV.7:
VEHICLE MILES OF TRAVEL BY VEHICLE AGE 1969-1990

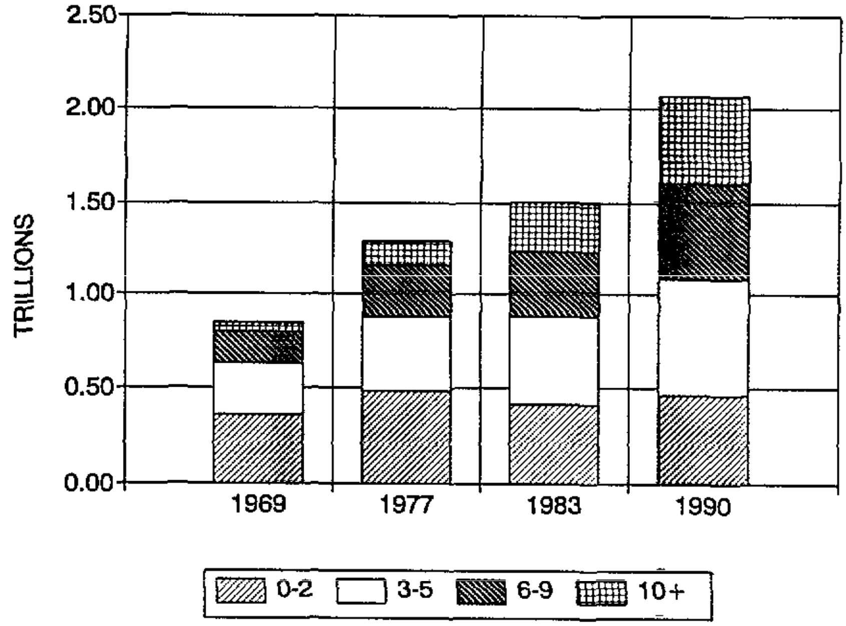
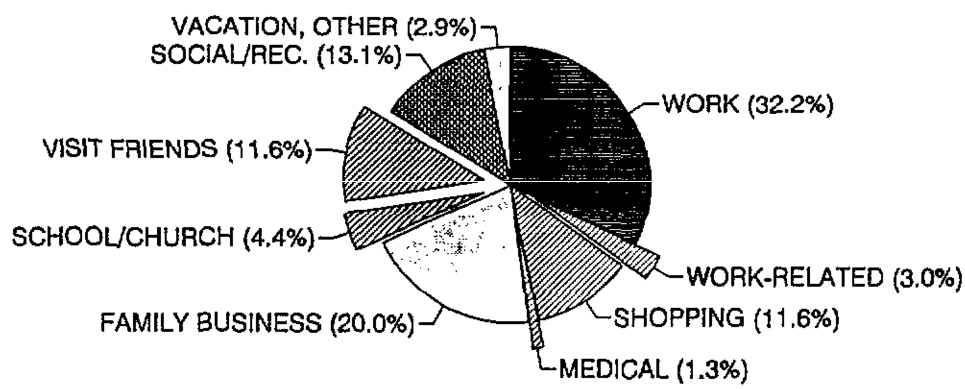


Figure IV.8:
SHARES OF VEHICLE MILES OF TRAVEL BY PURPOSE



Another way to look at the purpose-vehicle age relationship is to establish the vehicle age components of certain important purposes and determine the extent to which vehicles of certain ages differentially contribute to travel for that purpose. The most important of these is work travel. Figure IV.10 depicts the shares of work trips in vehicles, by age of vehicle. It indicates that, for instance, slightly more than 20 percent of work trips are made by vehicles of 1980 vintage or older. The share of all trips by this vehicle age group is between 18 and 19 percent. In work-related activities, vehicles that are two-or-less years old account for over 37 percent of work-connected business trips but account for less than 30 percent of all trips. The category Other Social and Recreational Travel exhibits a similar pattern, with just below 33 percent of "soc-rec" trips accounted for by newer vehicles vs 30 percent for vehicles of all ages.

Figure IV.9:
SHARE OF WORK TRIPS BY VEHICLE AGE
(AVERAGE SHARE OF ALL VEHICLES = 21.6%)

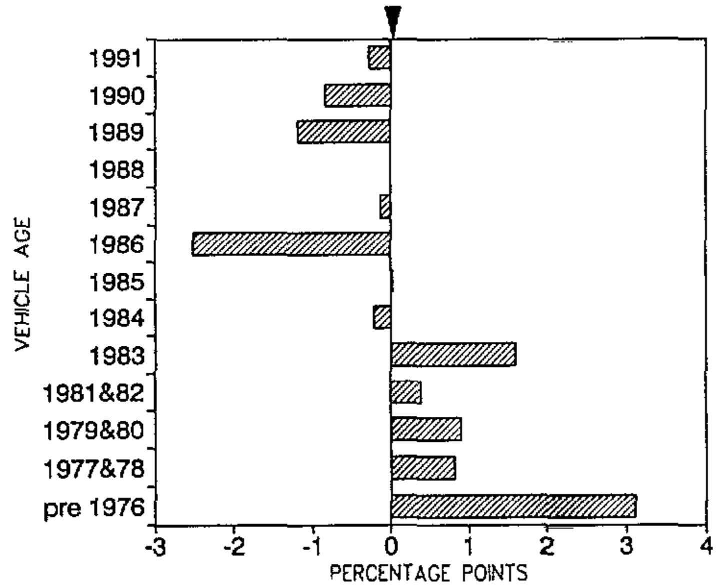
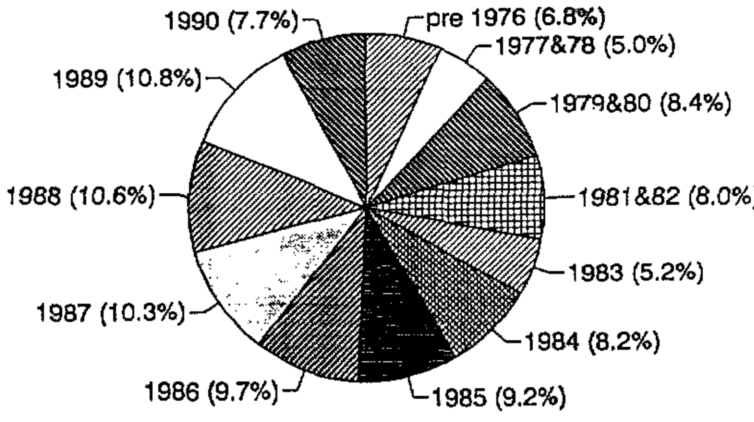


Figure IV.10:
SHARES OF WORK TRIPS BY AGE OF VEHICLE BY AGE GROUP 1976-1990



V. Safety, Energy and Pollution Effects

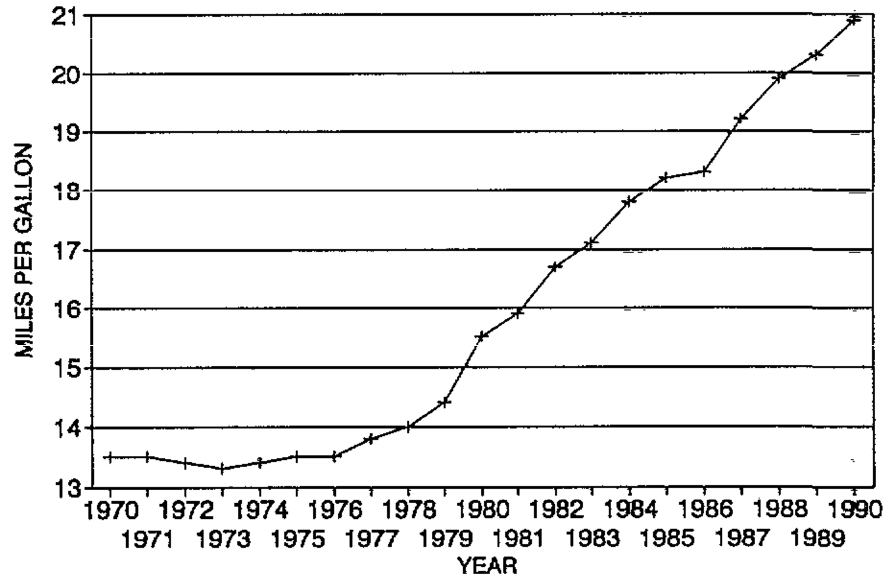
The implications of the shift in the character of the vehicle fleet is profound and can only be sketched here. The aging of the fleet has important consequences for the mobility of our population. Its most significant point in terms of public policy impact is the lag in penetration into the vehicle fleet of innovations that are being developed now in areas such as fuel efficiency, pollution generation, and safety.

The fuel consumption characteristics of this older fleet clearly lag that of the newer fleet. Figure V.1 shows the significant gains achieved in fuel economy of the vehicle fleet by year. From a level of about 13.5 miles per gallon when the first energy shock hit in the early 70's the fuel economy of the fleet has risen to a level approximating 21 miles per gallon by 1990. This suggests that for each mile of VMT occurring in older vehicles we pay a substantial energy penalty. These averages, of course, reflect the fleet composition by age as of 1990. The actual sales-weighted fuel economy for 1990 vehicles was 27.6 for autos, 20.5 for light trucks, averaging 24.8 for the 1990 fleet.

The air pollution control consequences are probably even more pronounced. The year 1981 was a key turning point in the air quality control characteristics of the vehicle fleet. The differences in pollution per vehicle mile for vehicles pre- and post-1981 are extraordinary. A national focus on the characteristics of the aging fleet is critical. The NPTS can be valuable policy research resource in responding to this challenge. This is a key place to start to really attack the pollution problems in America.

In terms of safety there are so many new safety features—anti-lock brakes, airbags, traction control, etc.—that will only slowly gain penetration into the fleet that the implications for accidents, injuries and deaths is frightening. The approaching opportunities of IVHS will be diminished by the slow rate of adoption of new technologies that are dependent on new vehicle development. Many of the benefits of a fleet that lasts longer, and they are substantial, for resource conservation and minimizing junk yards, and other aspects of a disposable fleet may be lost if the benefits of penetration of the fleet with positive technological advances are not achieved.

Figure V.1
VEHICLE FLEET FUEL ECONOMY BY YEAR 1970-1990



SOURCE: HWY STATISTICS; FHWA

Appendix Table: DETAILED PERCENT DISTRIBUTION OF VEHICLES BY AGE AND VEHICLE TYPE

Vehicle Age	Autos	Truck/Van	RV's	Total
<=1	6.4	8.8	11.6	7.0
2	9.2	10.9	4.8	9.6
3	8.9	9.7	5.8	9.1
4	9.1	9.1	2.3	9.0
5	9.7	8.4	3.1	9.4
6	9.0	7.5	6.1	8.6
7	7.9	6.3	5.7	7.5
8	5.2	3.8	4.5	4.9
9	4.6	3.3	1.2	4.3
>=10	30.0	32.2	54.9	30.6
Number of Vehicles				
(000's)	120,712	37,110	821	158,543
Average Age	7.6	8.0	10.4	7.7

Source: ORNL

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

Ryuichi Kitamura and the Department of Transportation Engineering, Kyoto University

Acknowledgments

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

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

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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

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	

Table 2.6: DISTRIBUTION OF TRIPS BY RECORDED STARTING MINUTE

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.

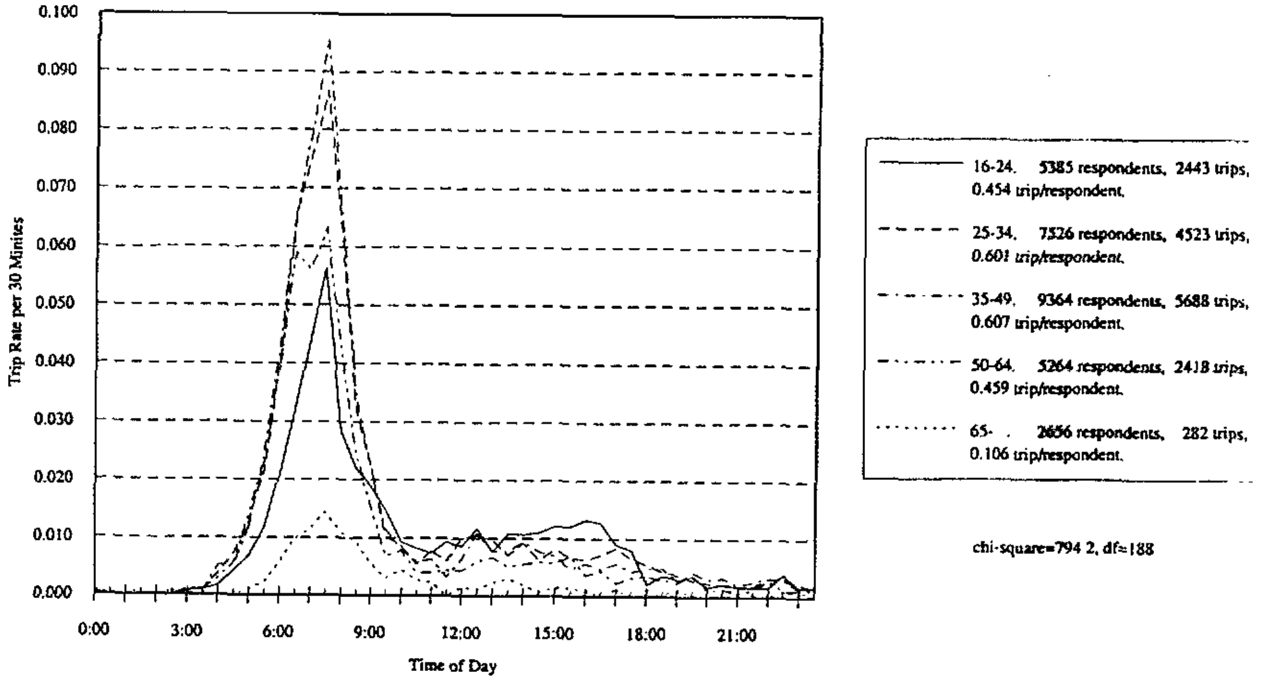

Figure 3.1.a Distribution of Trip Starting Times by Age: To work

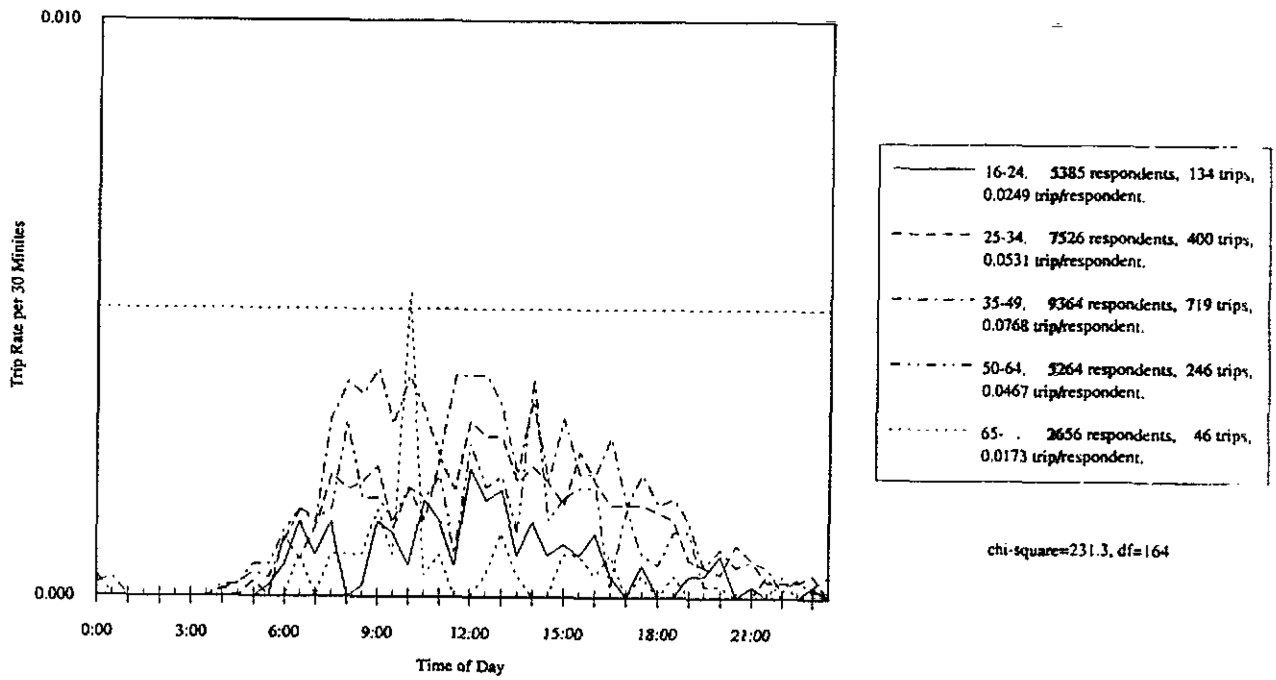

Figure 3.1.b Distribution of Trip Starting Times by Age: Work-related business

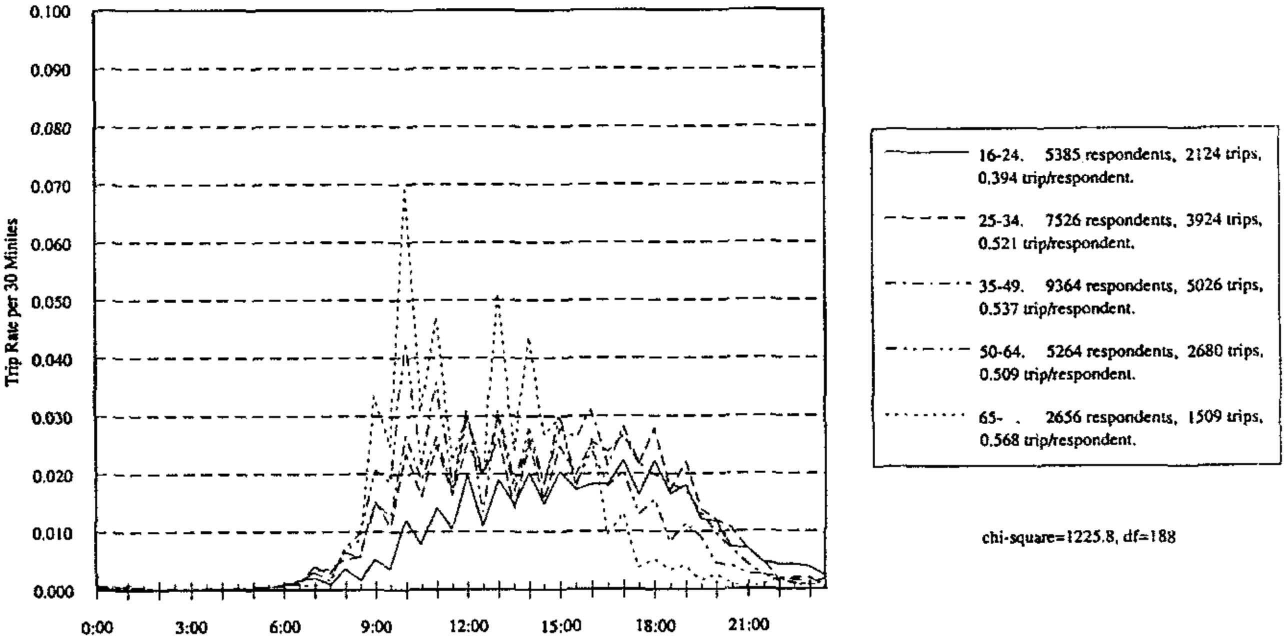

Figure 3.1.c Distribution of Trip Starting Times by Age: Shopping

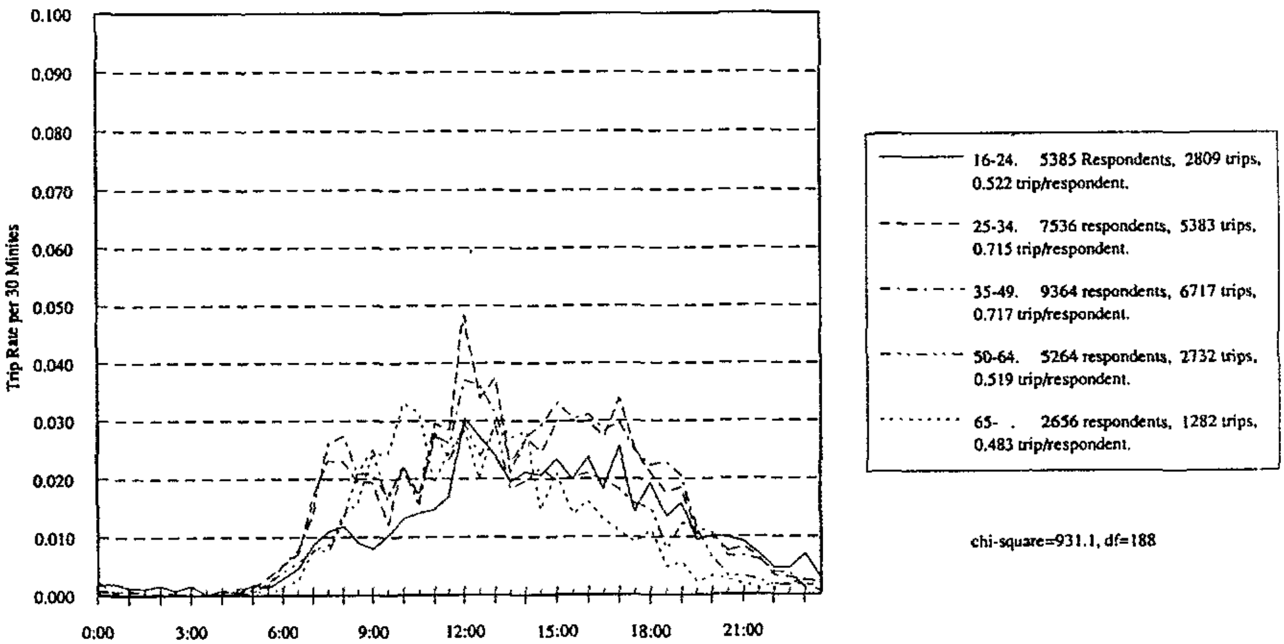

Figure 3.1.d Distribution of Trip Starting Times by Age: Other family or personal business

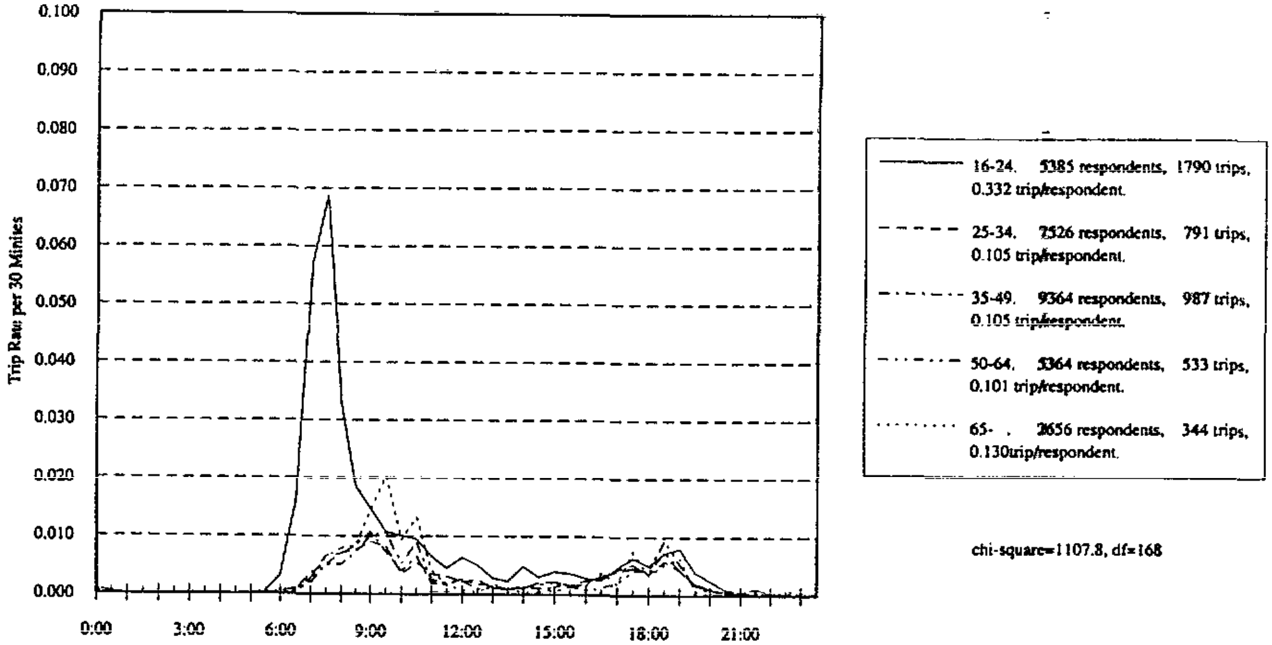

Figure 3.1.e Distribution of Trip Starting Times by Age: School/church

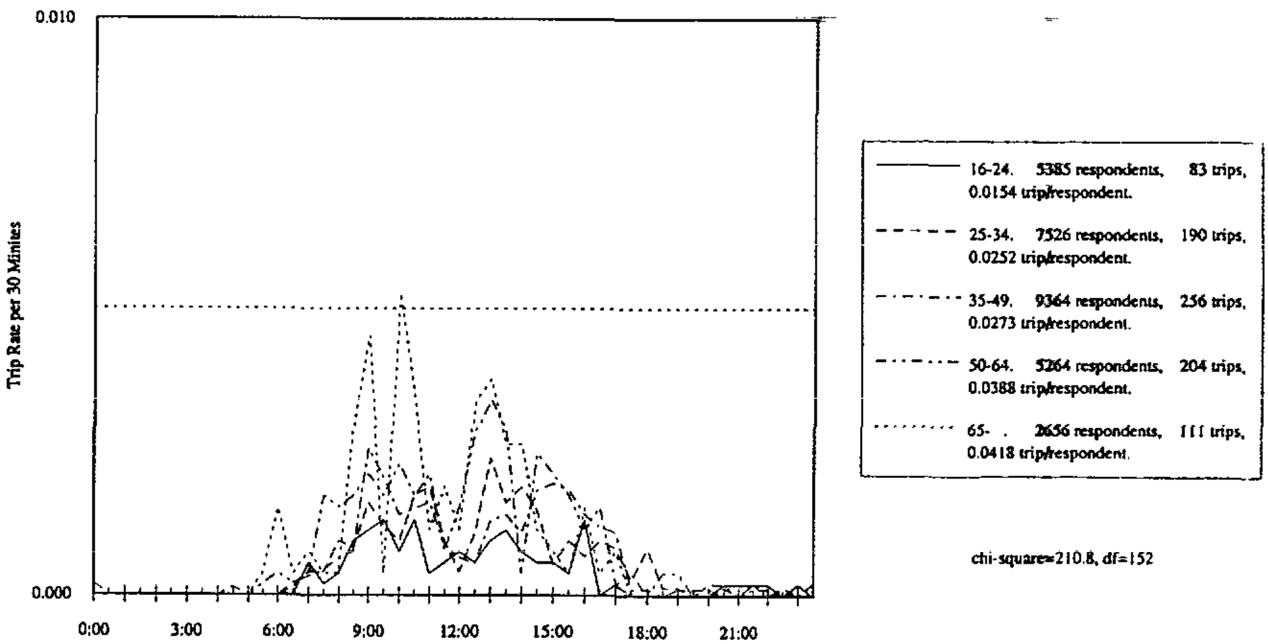

Figure 3.1.f Distribution of Trip Starting Times by Age: Doctor/dentist

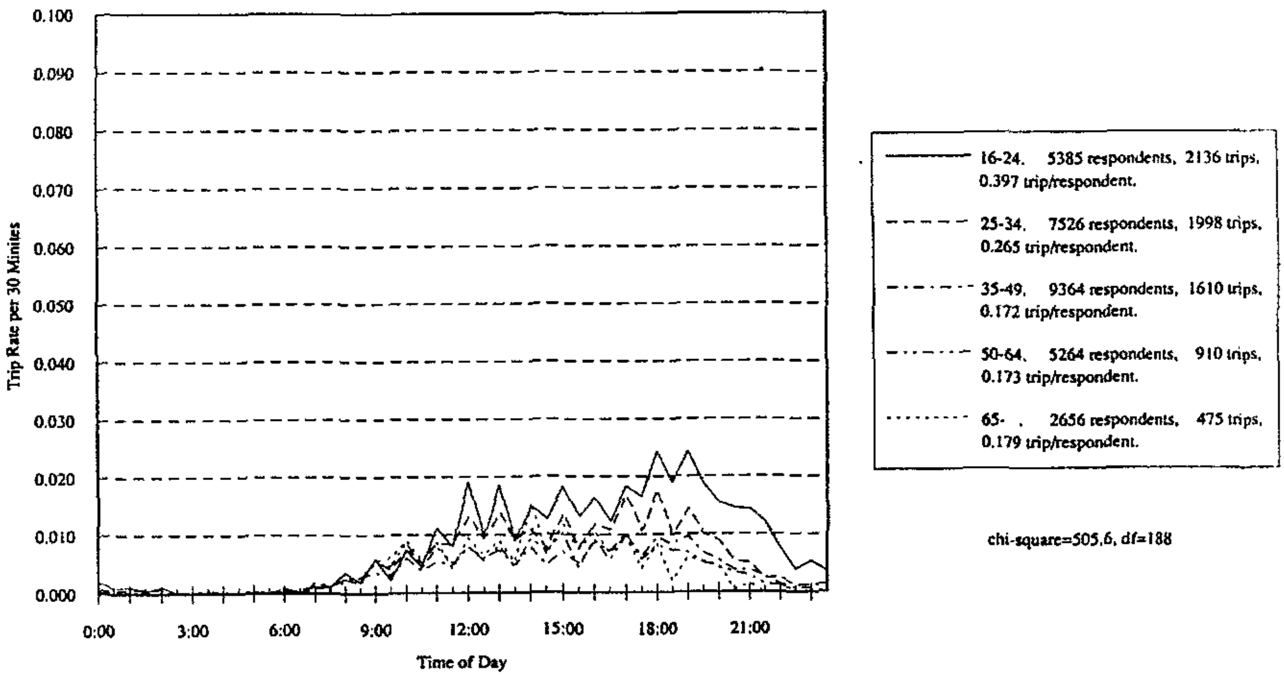

Figure 3.1.g Distribution of Trip Starting Times by Age: Visit friends or relatives

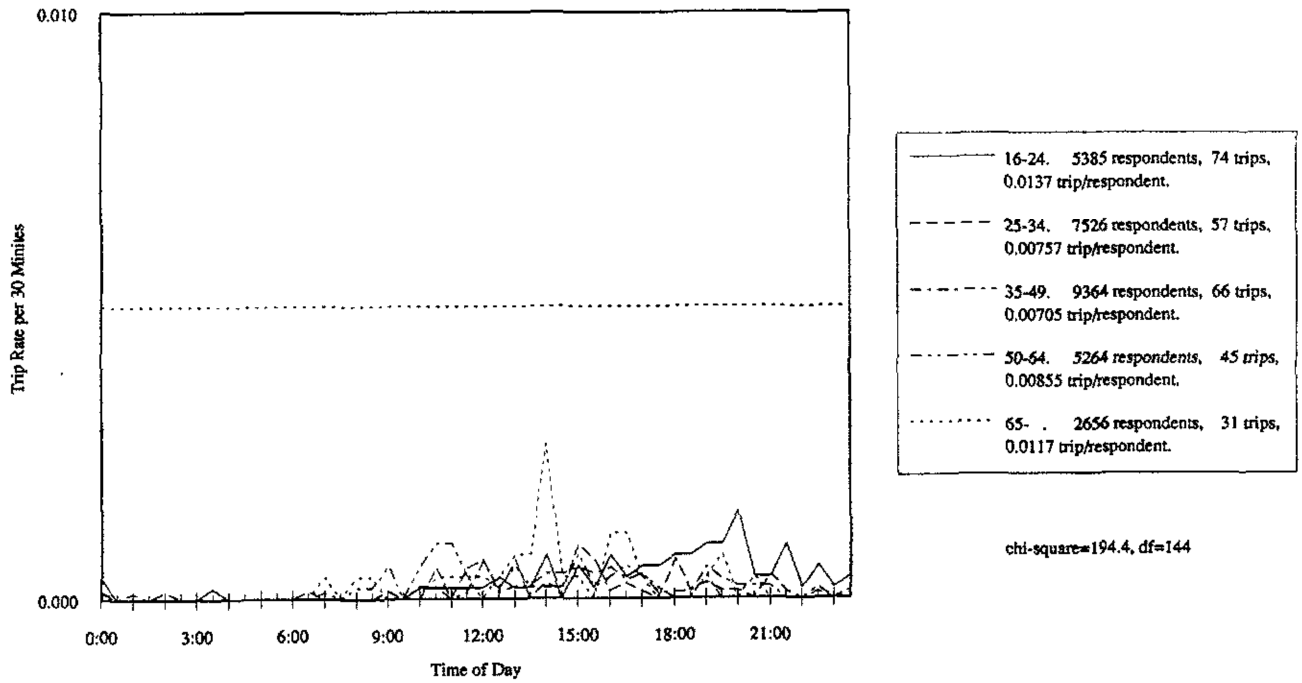

Figure 3.1.h Distribution of Trip Starting Times by Age: Pleasure driving

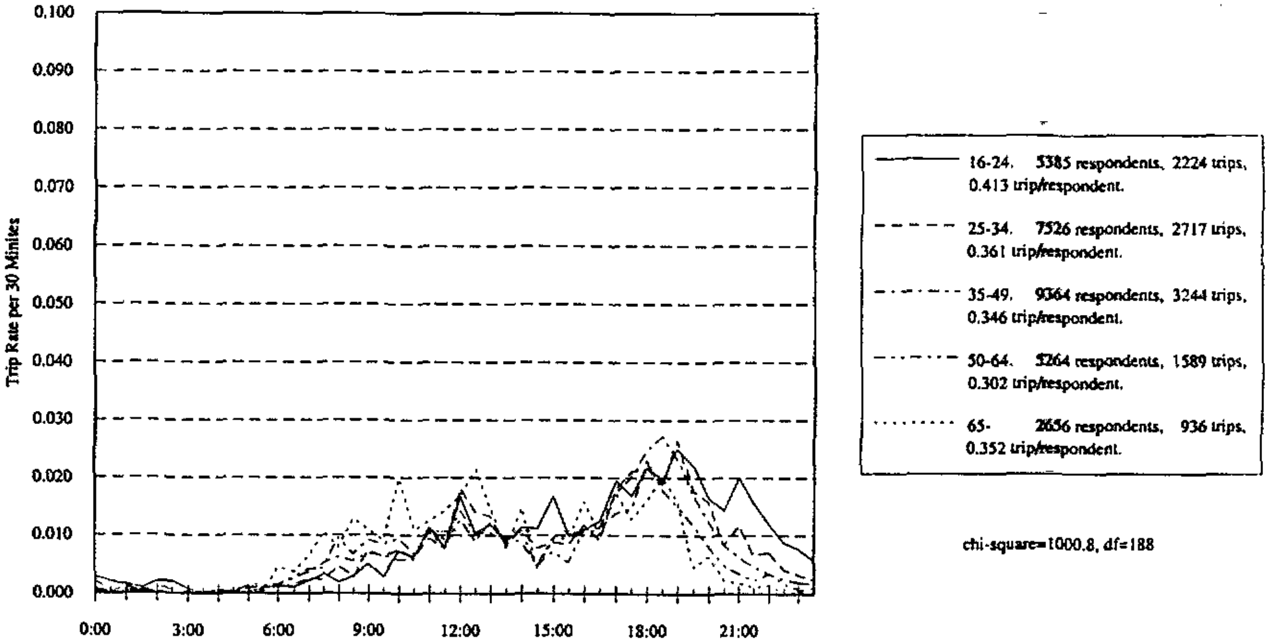

Figure 3.1.i Distribution of Trip Starting Times by Age: Other social or recreational

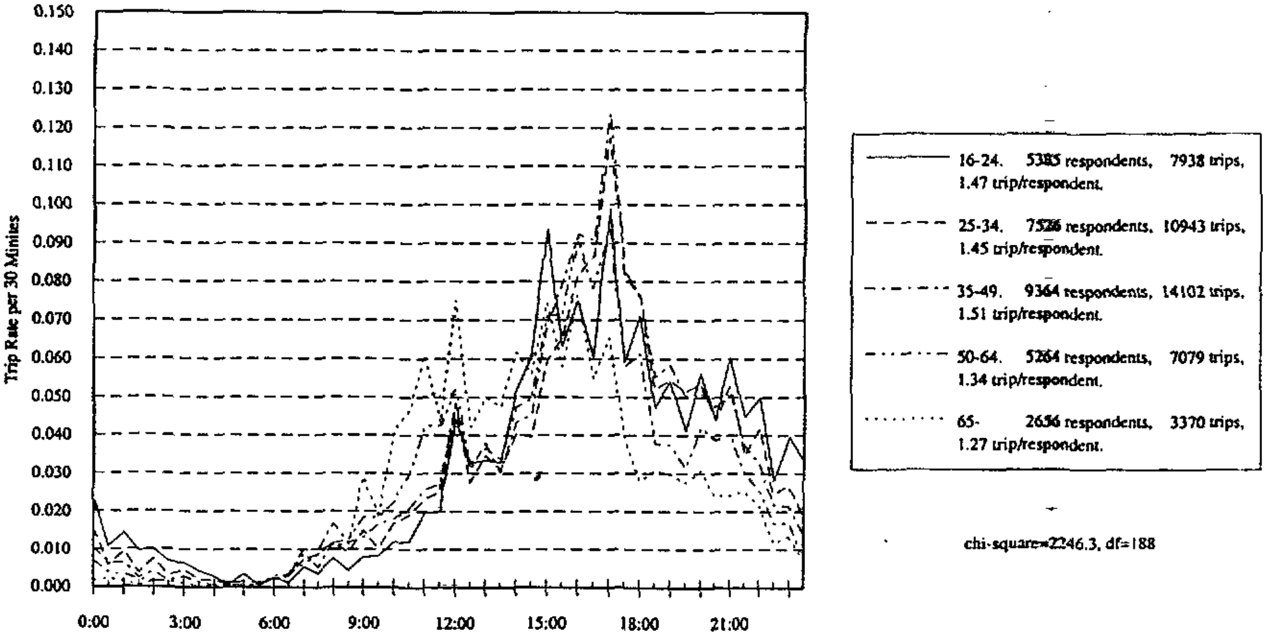

Figure 3.1.j Distribution of Trip Starting Times by Age: To home

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.

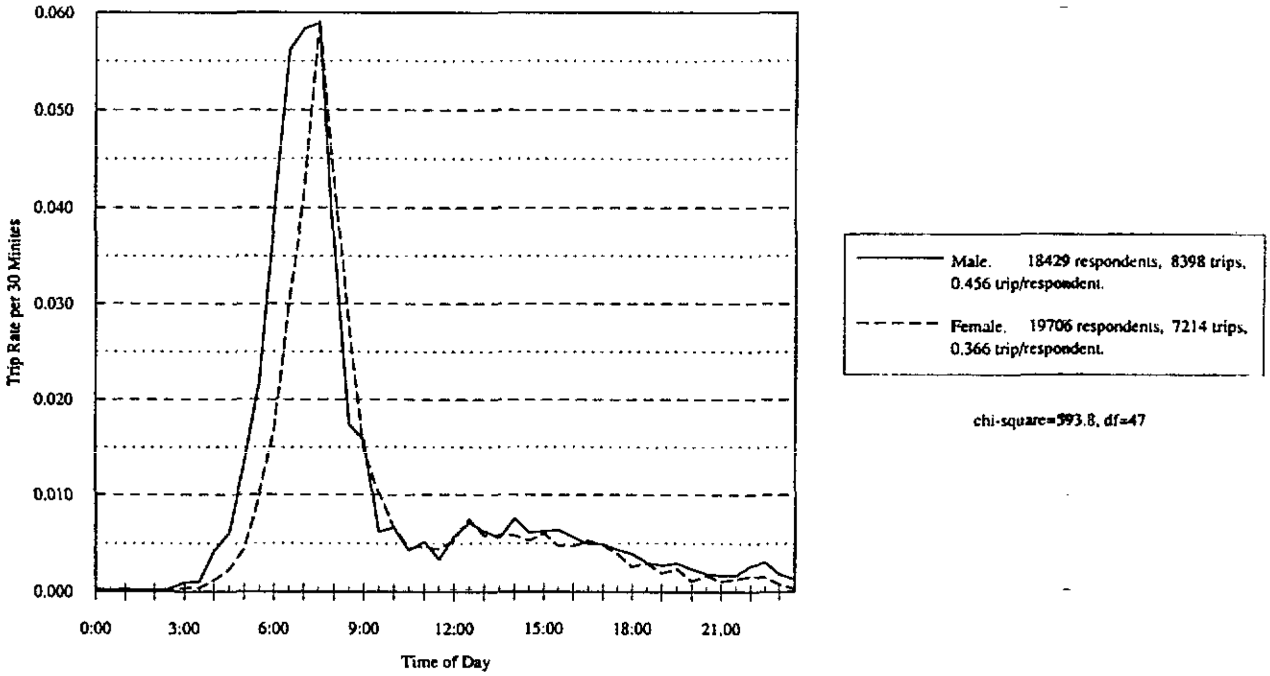

Figure 3.2.a Distribution of Trip Starting Times by Sex: To work

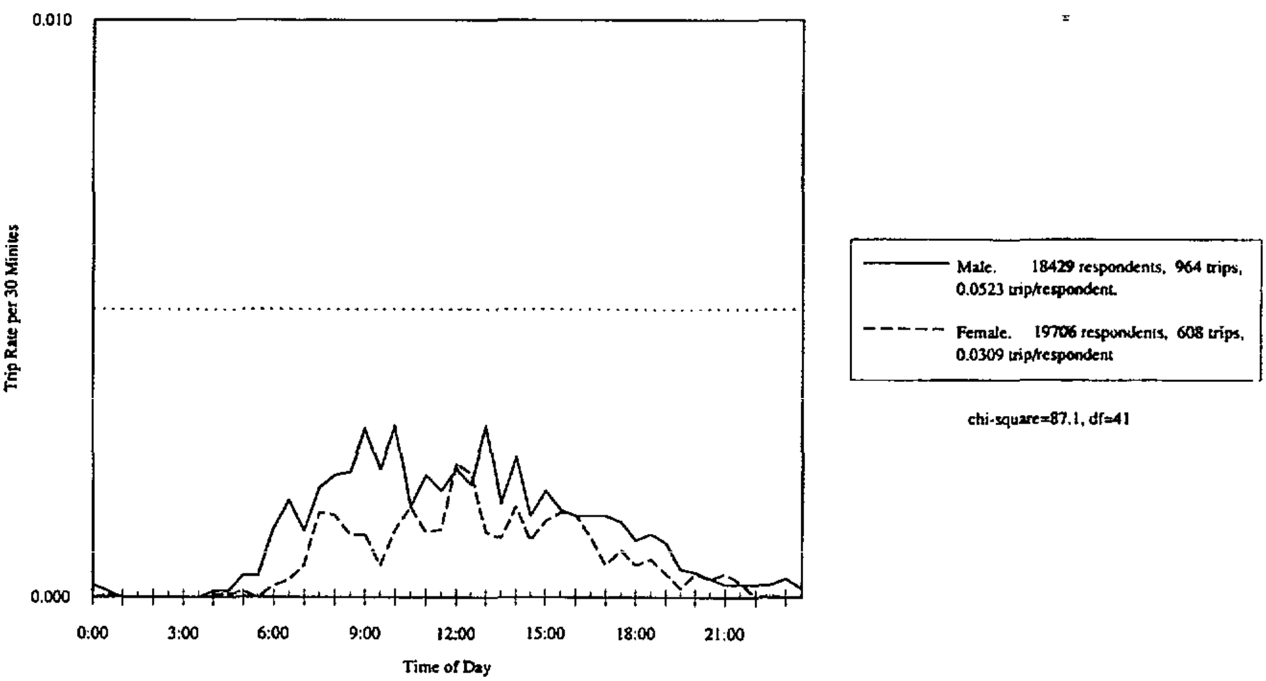

Figure 3.2.b Distribution of Trip Starting Times by Sex: Work-related business

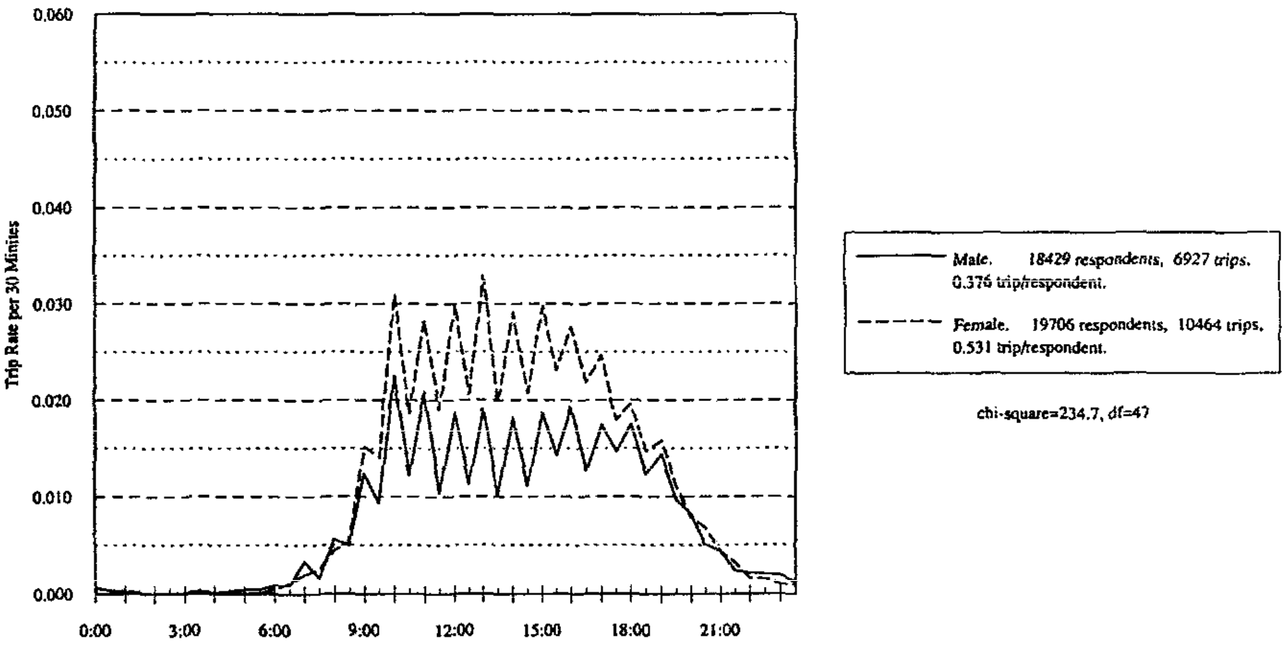

Figure 3.2.c Distribution of Trip Starting Times by Sex:Shopping

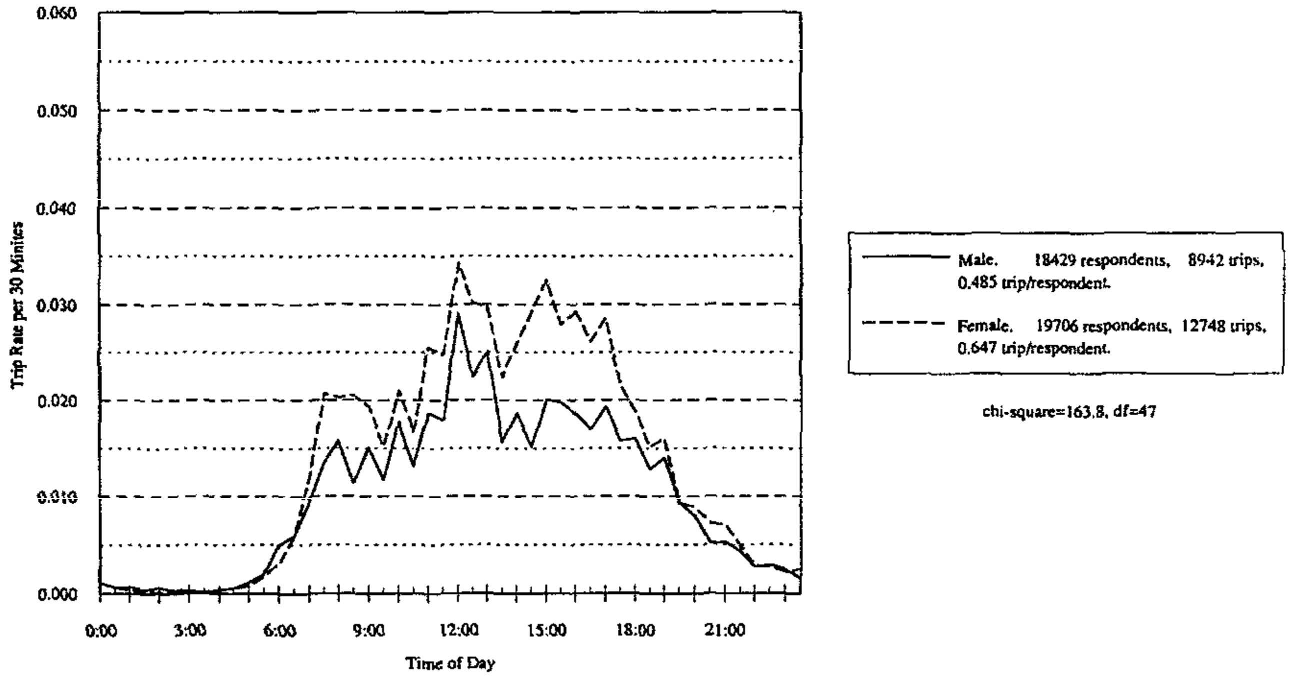

Figure 3.2.d Distribution of Trip Starting Times by Sex: Other family or personal business

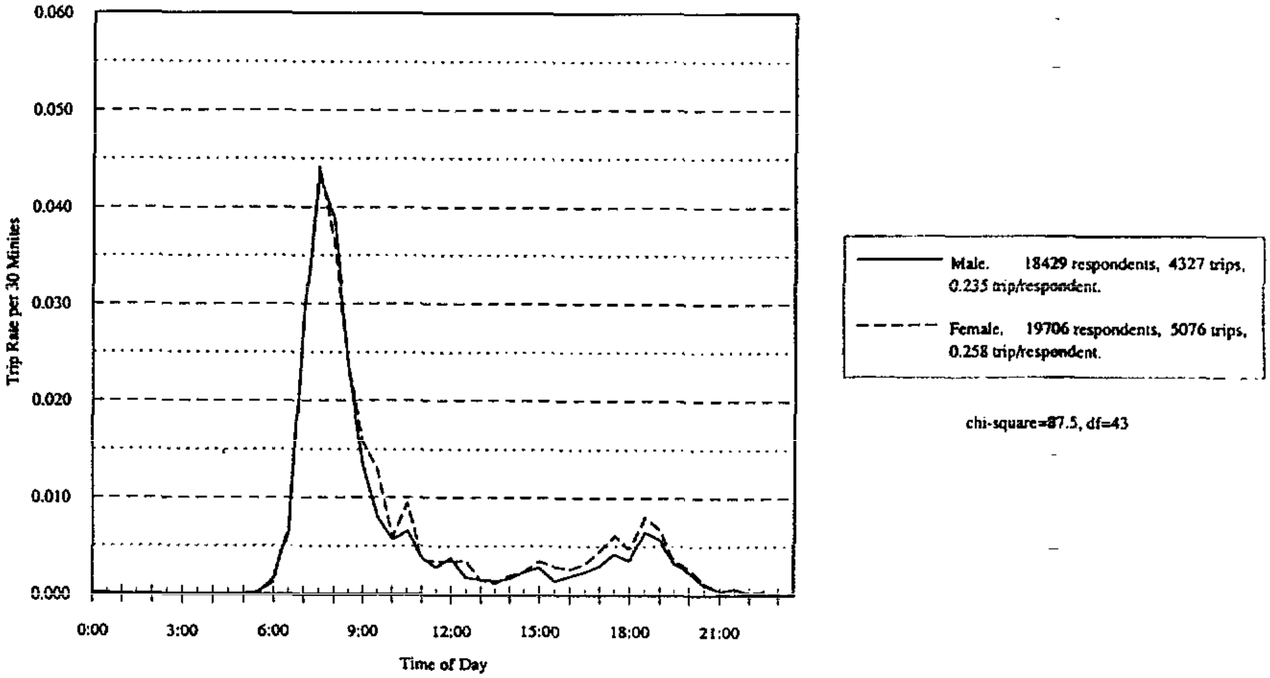

Figure 3.2.e Distribution of Trip Starting Times by Sex: School/church

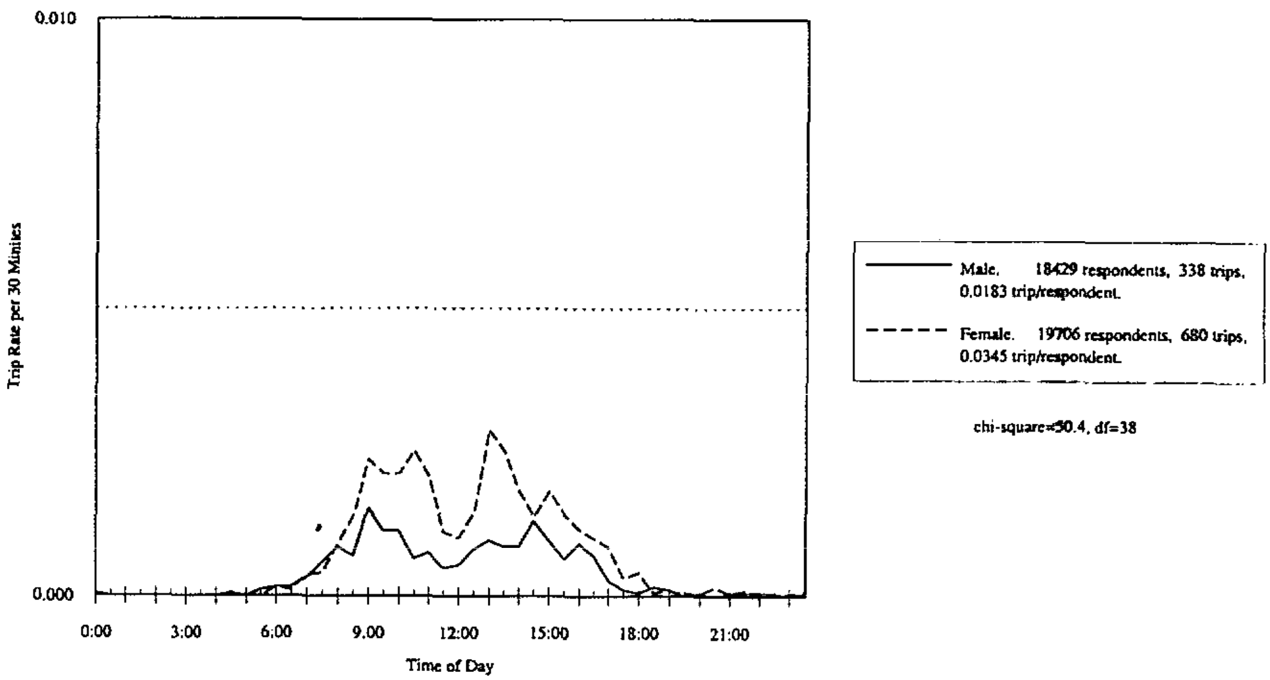

Figure 3.2.f Distribution of Trip Starting Times by Sex: Doctor/dentist

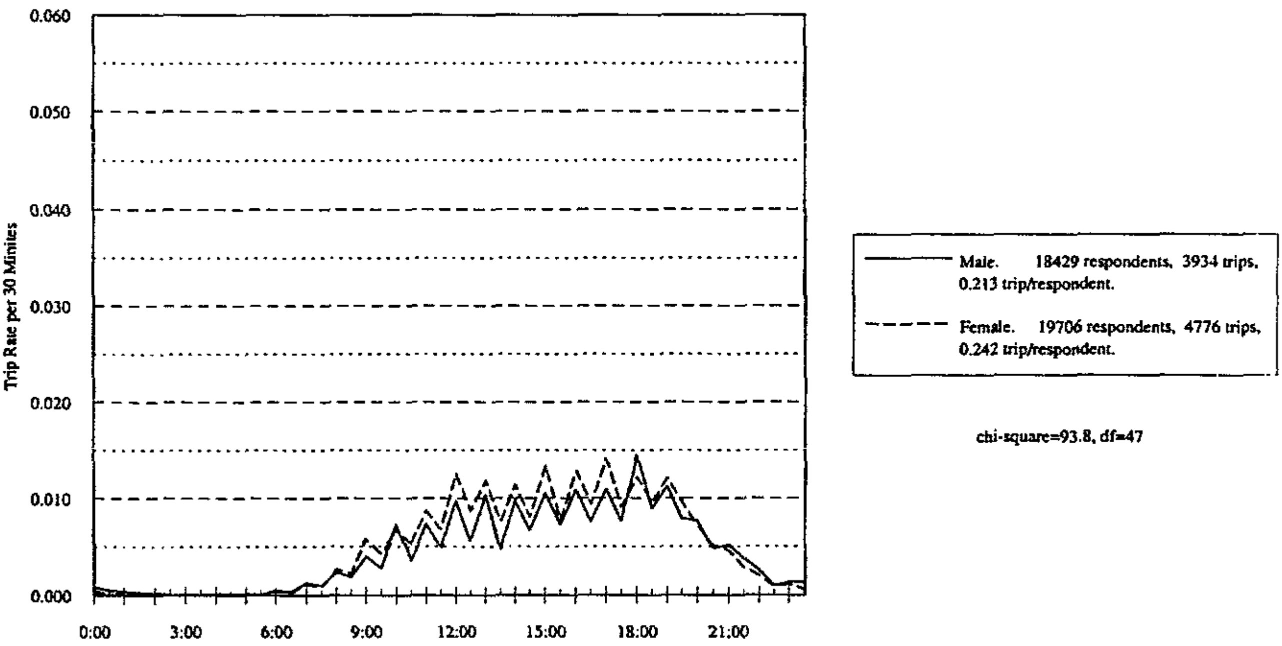

Figure 3.2.g Distribution of Trip Starting Times by Sex: Visit friends or relatives

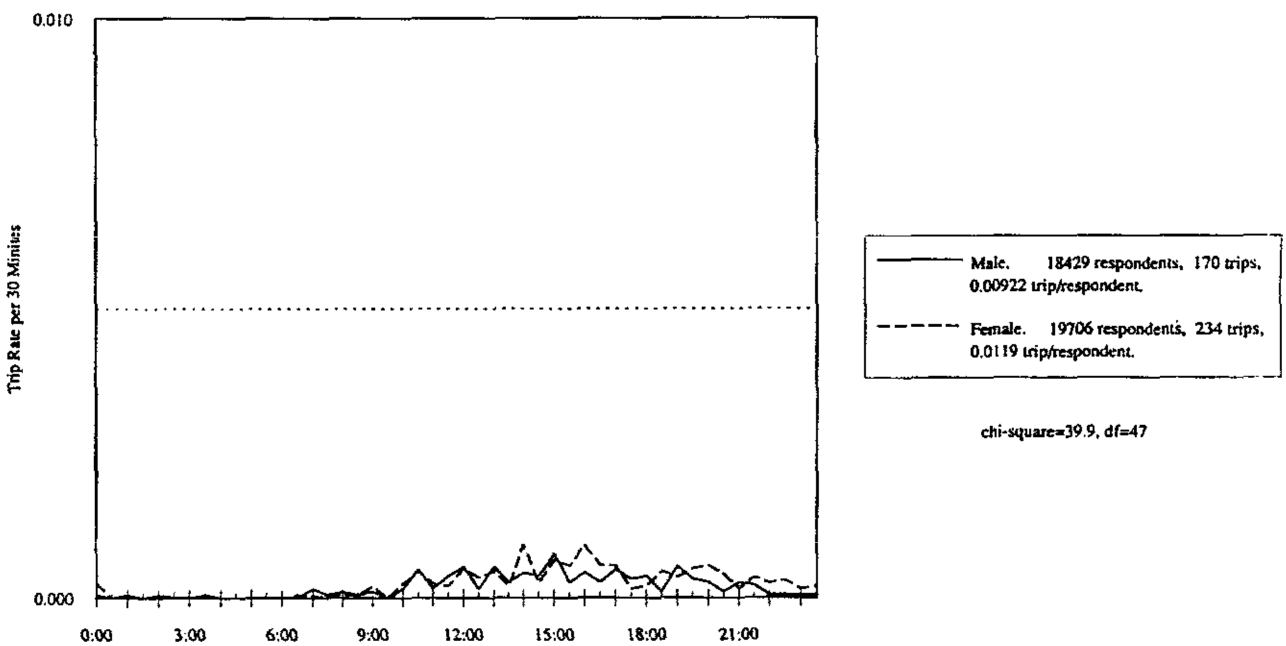

Figure 3.2.h Distribution of Trip Starting Times by Sex: Pleasure driving

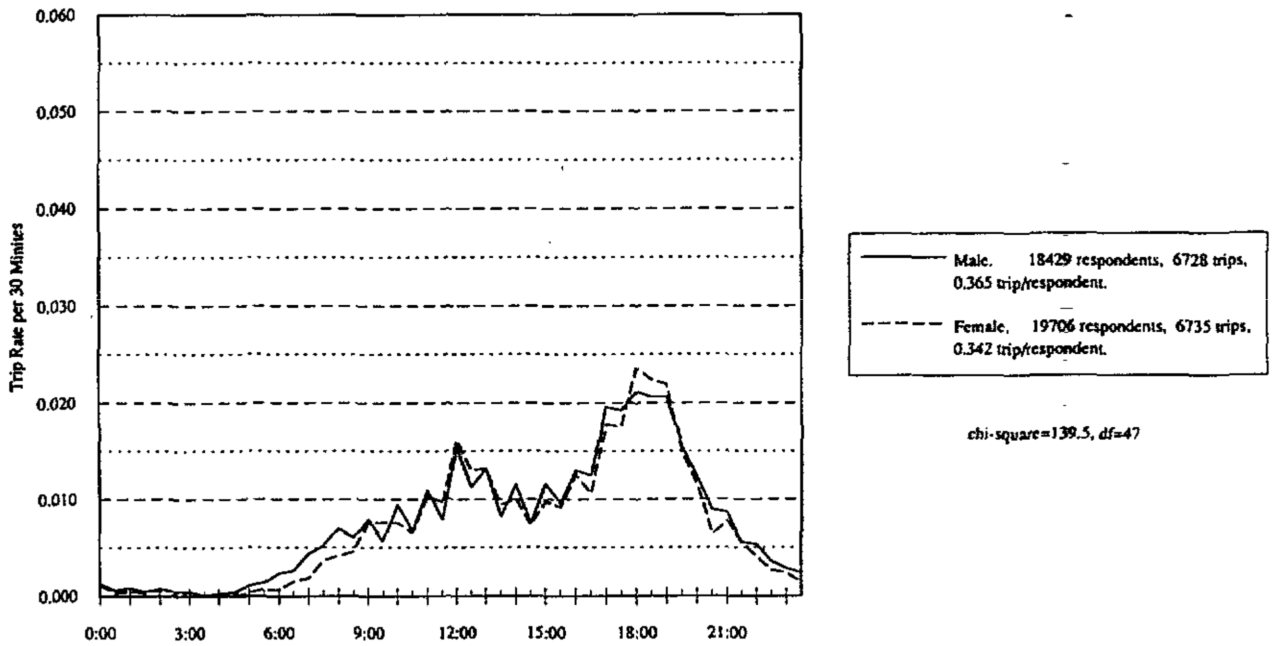

Figure 3.2.i Distribution of Trip Starting Times by Sex: Other social or recreational

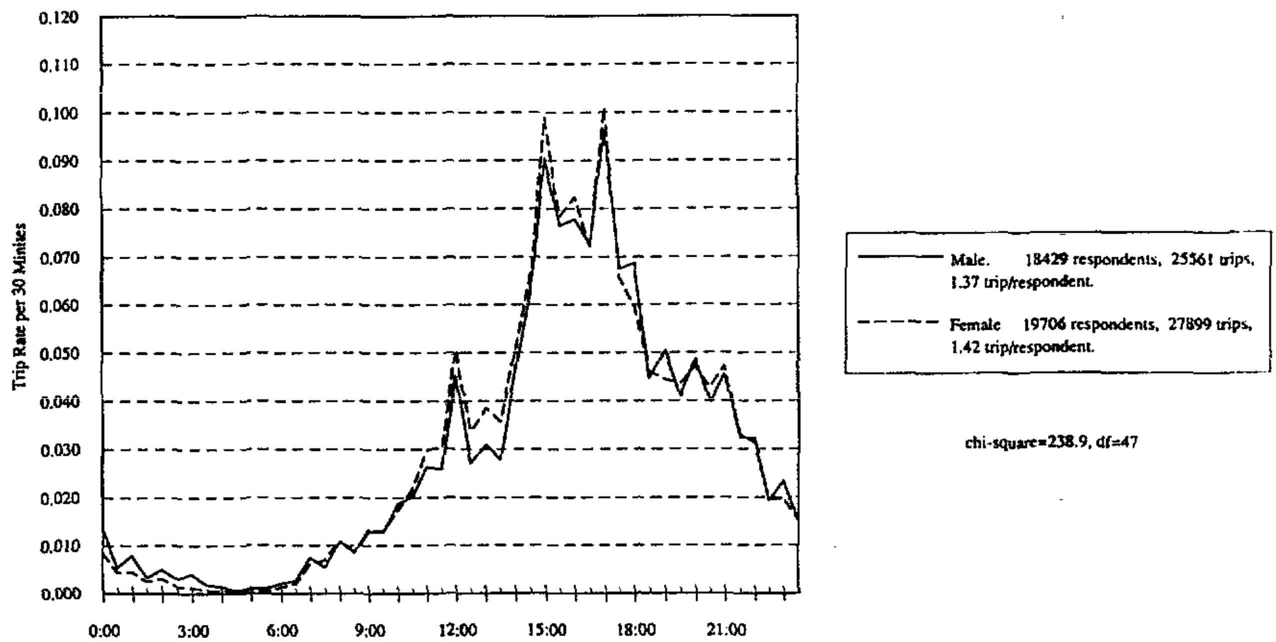

Figure 3.2.j Distribution of Trip Starting Times by Sex: To home

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.

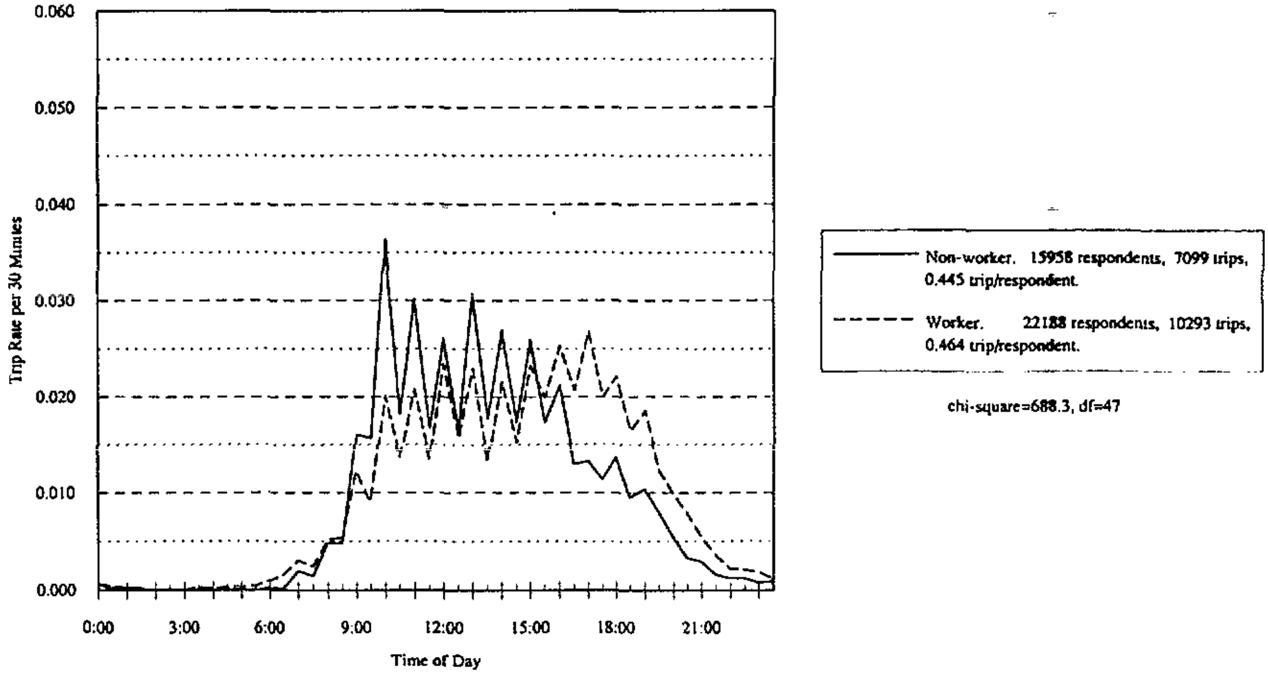

Figure 3.3.a Distribution of Trip Starting Times by Employment: Shopping

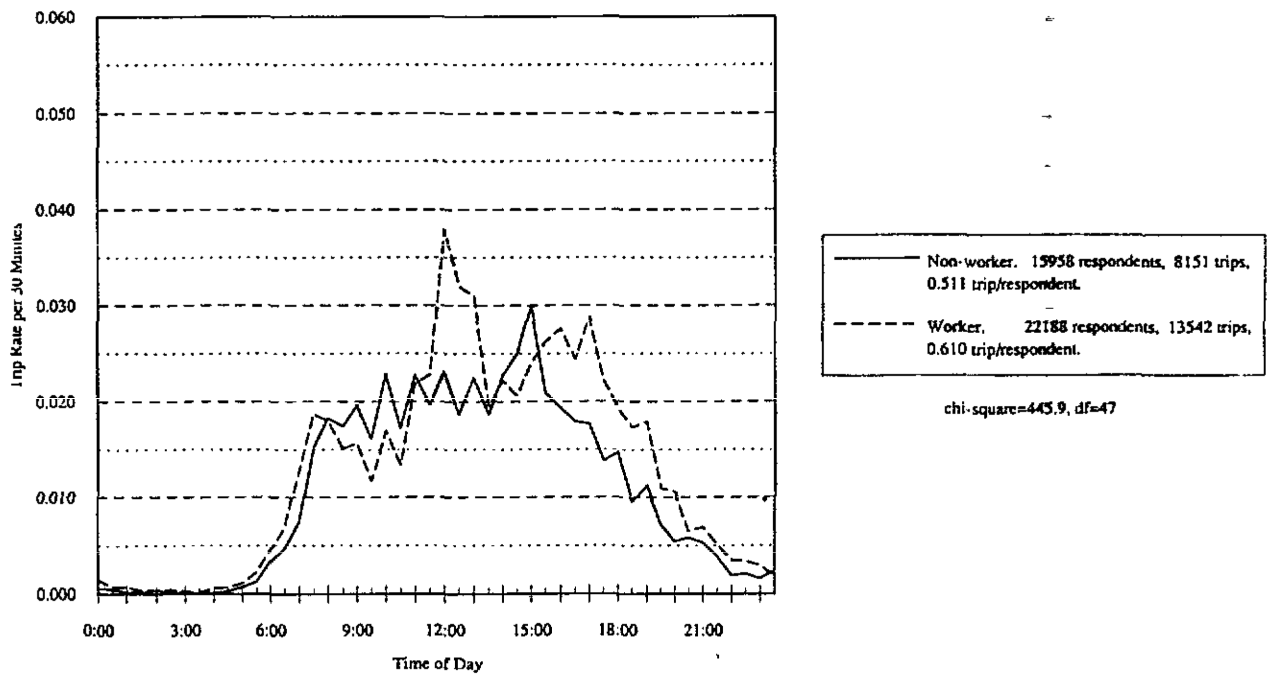

Figure 3.3.b Distribution of Trip Starting Times by Employment: Other family or personal business

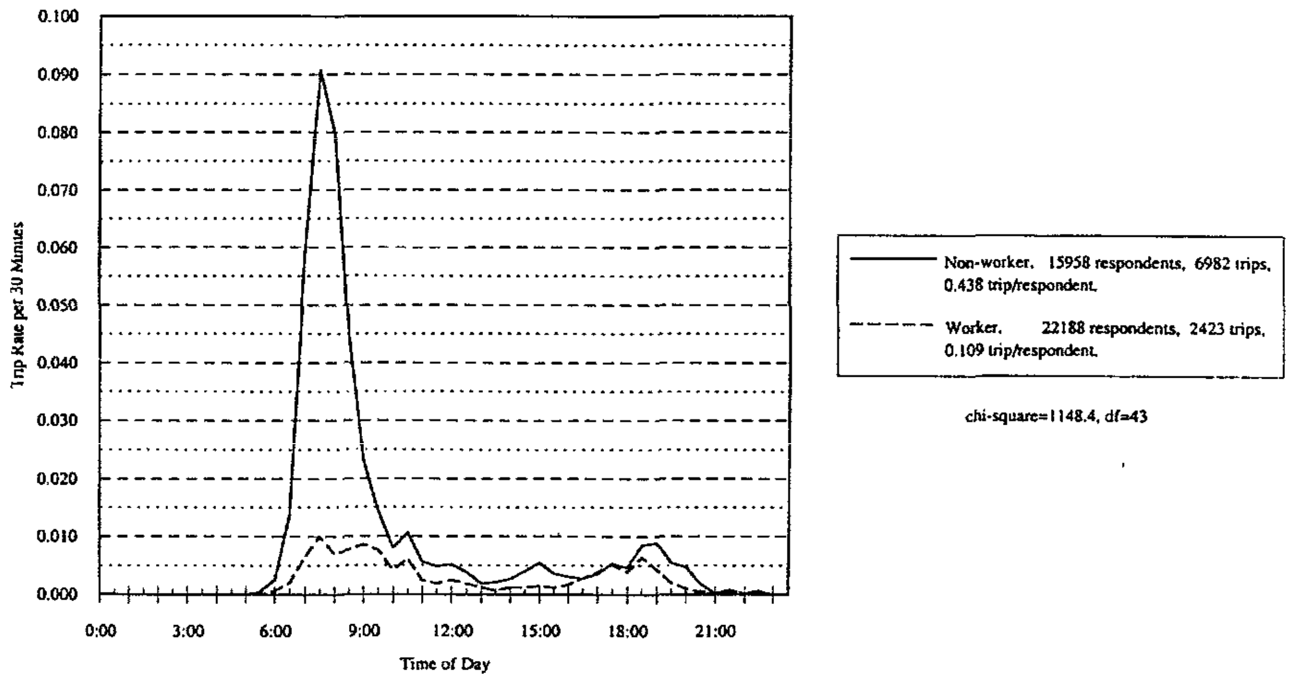

Figure 3.3.c Distribution of Trip Starting Times by Employment: School/church

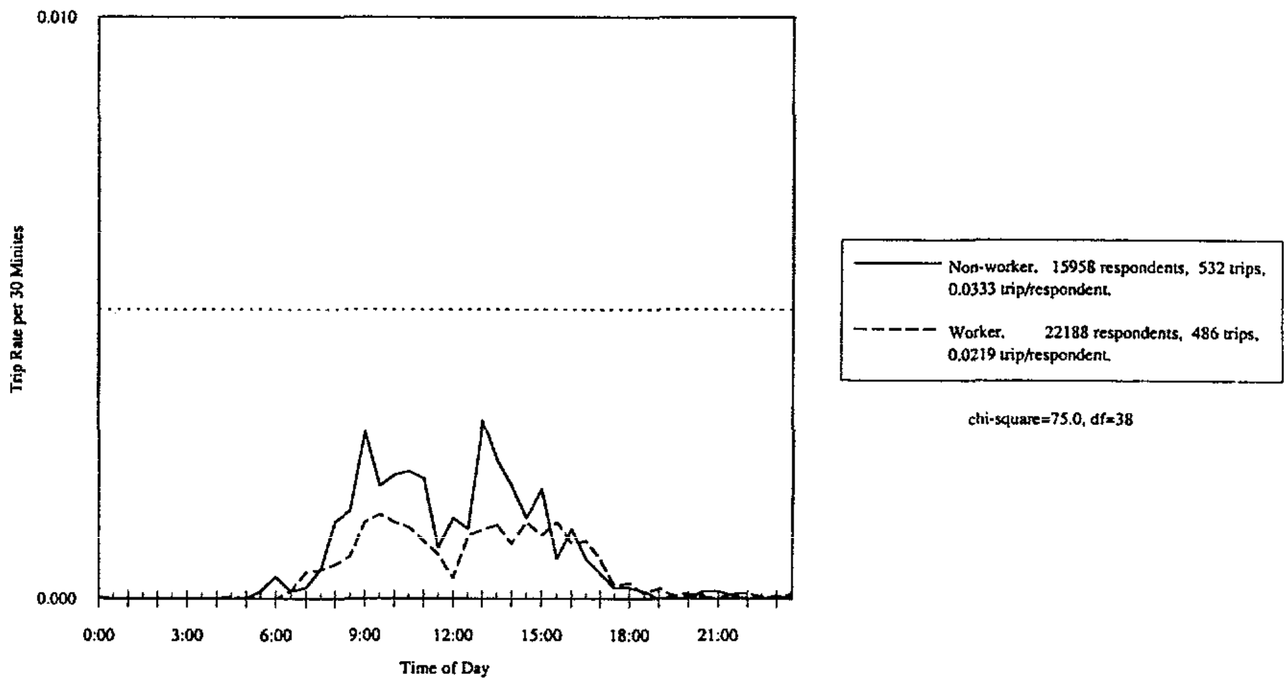

Figure 3.3.d Distribution of Trip Starting Times by Employment: Doctor/dentist

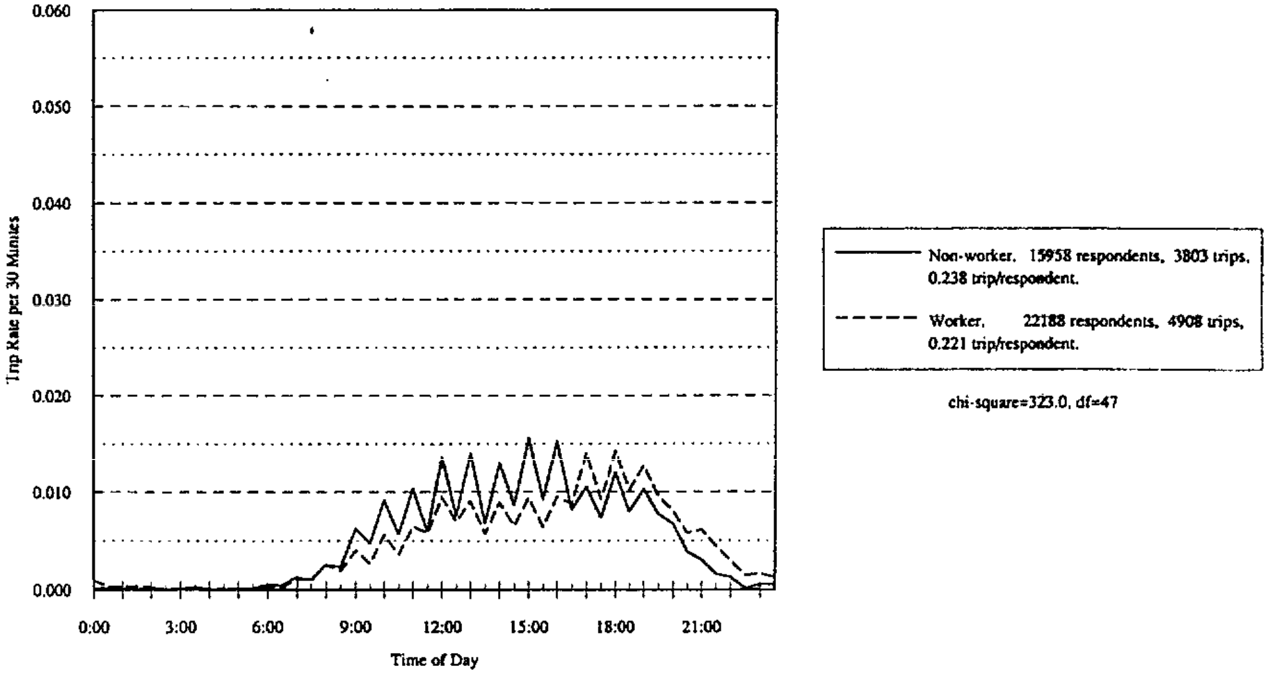

Figure 3.3.e Distribution of Trip Starting Times by Employment: Visit friends or relatives

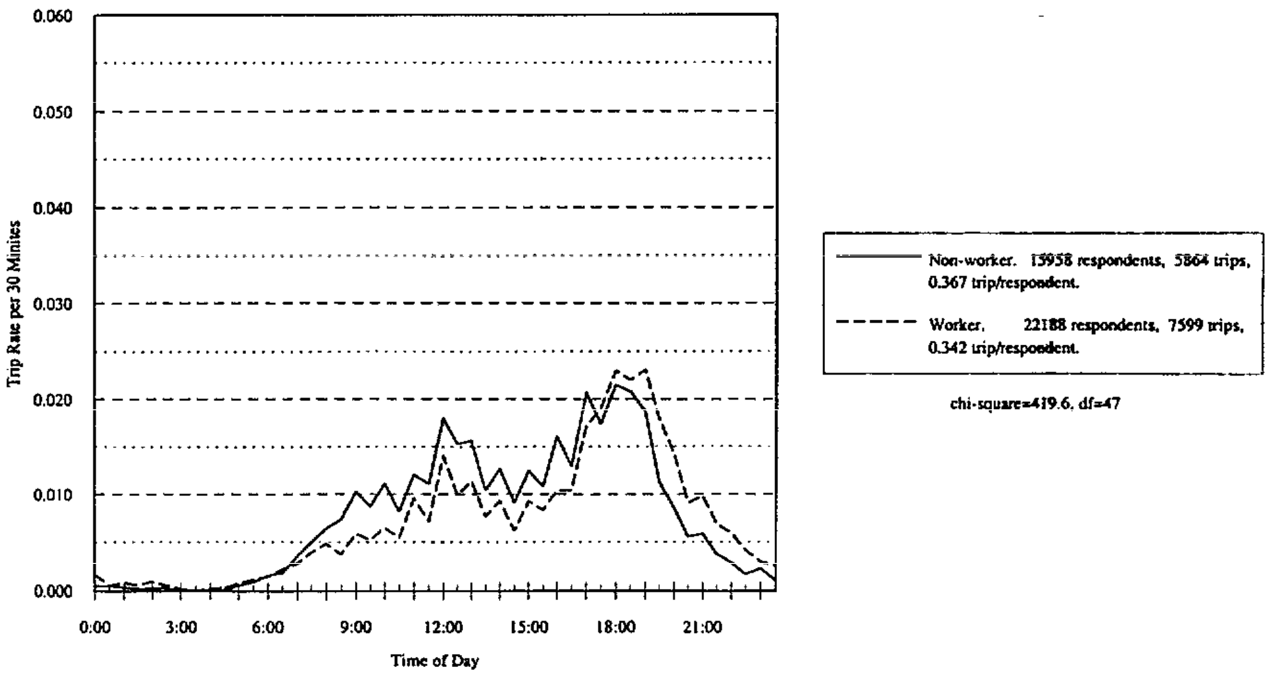

Figure 3.3.f Distribution of Trip Starting Times by Employment: Other social or recreational

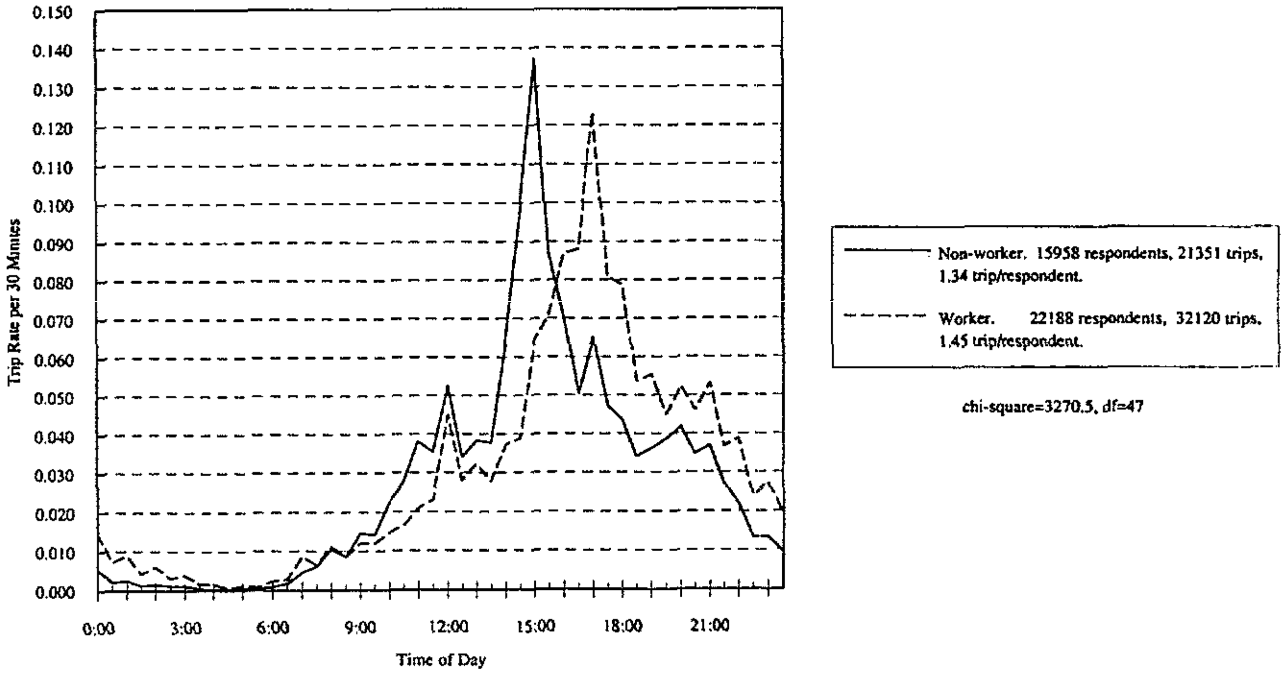

Figure 3.3.g Distribution of Trip Starting Times by Employment: To home

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.

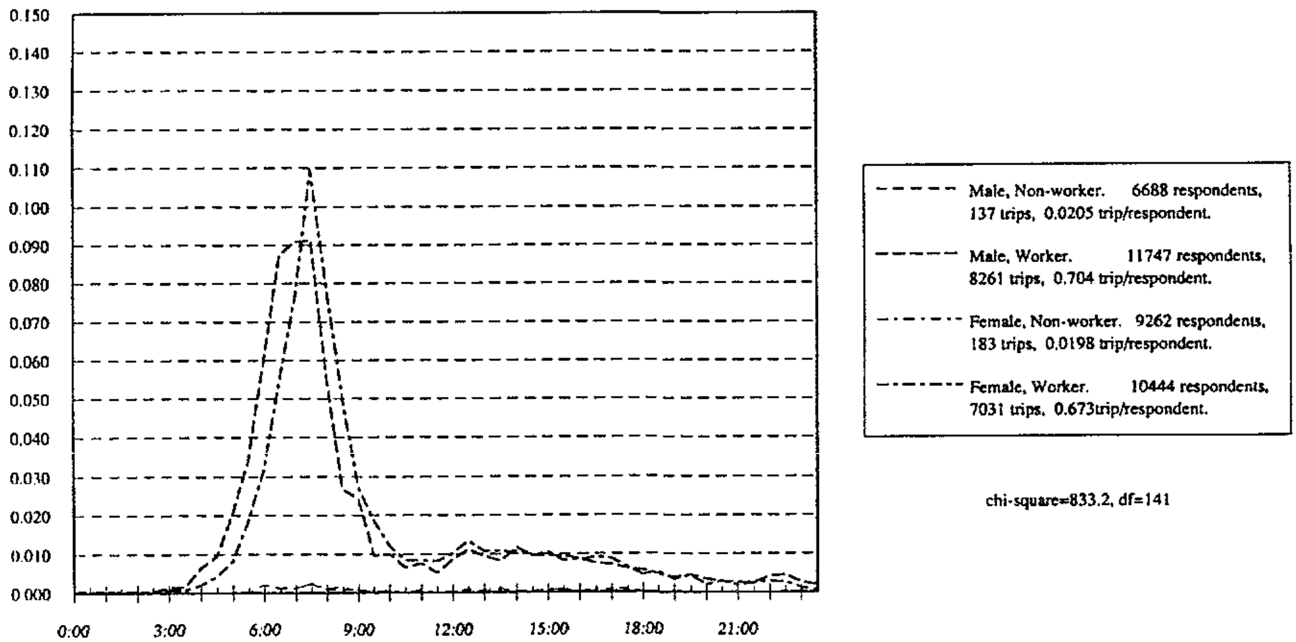

Figure 3.4.a Distribution of Trip Starting Times by Role: To work

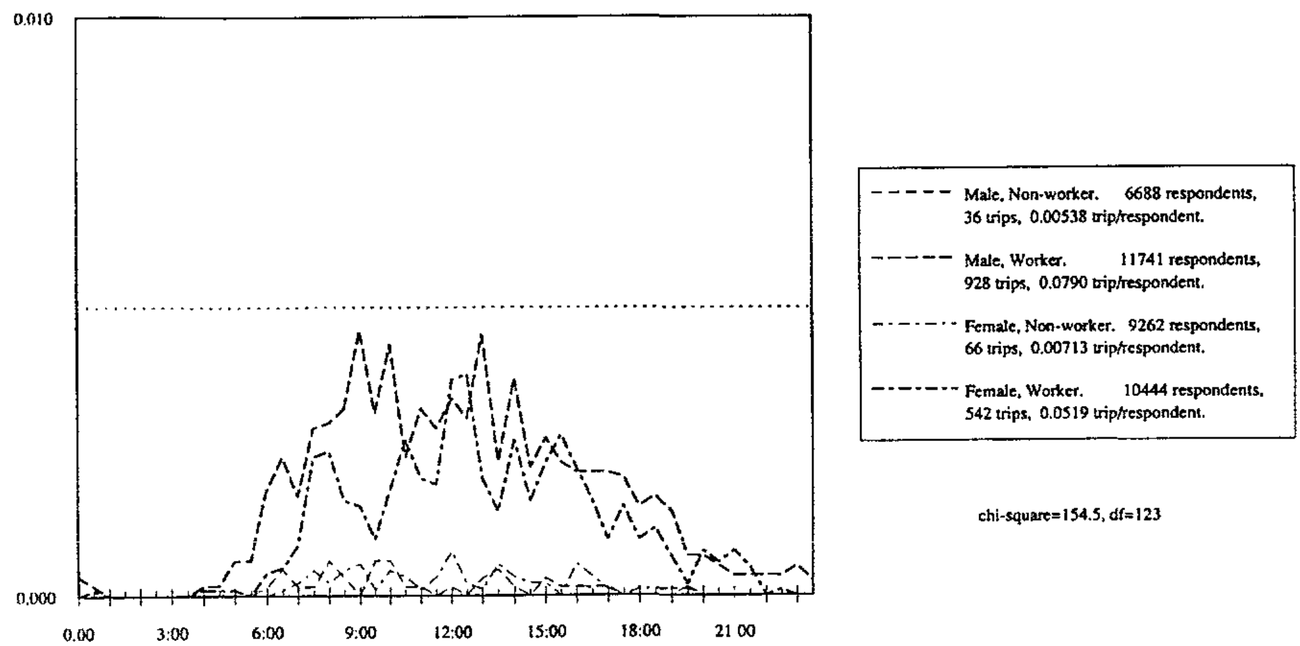

Figure 3.4.b Distribution of Trip Starting Times by Role: Work-related business

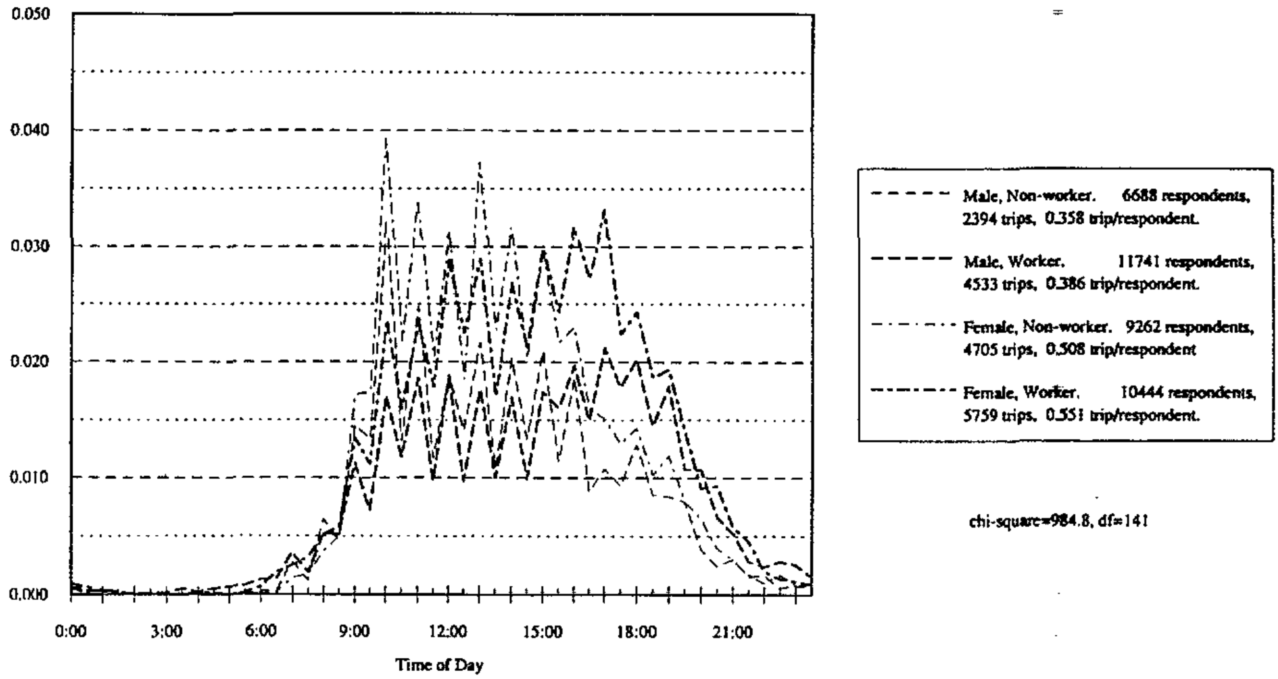

Figure 3.4.c Distribution of Trip Starting Times by Role: Shopping

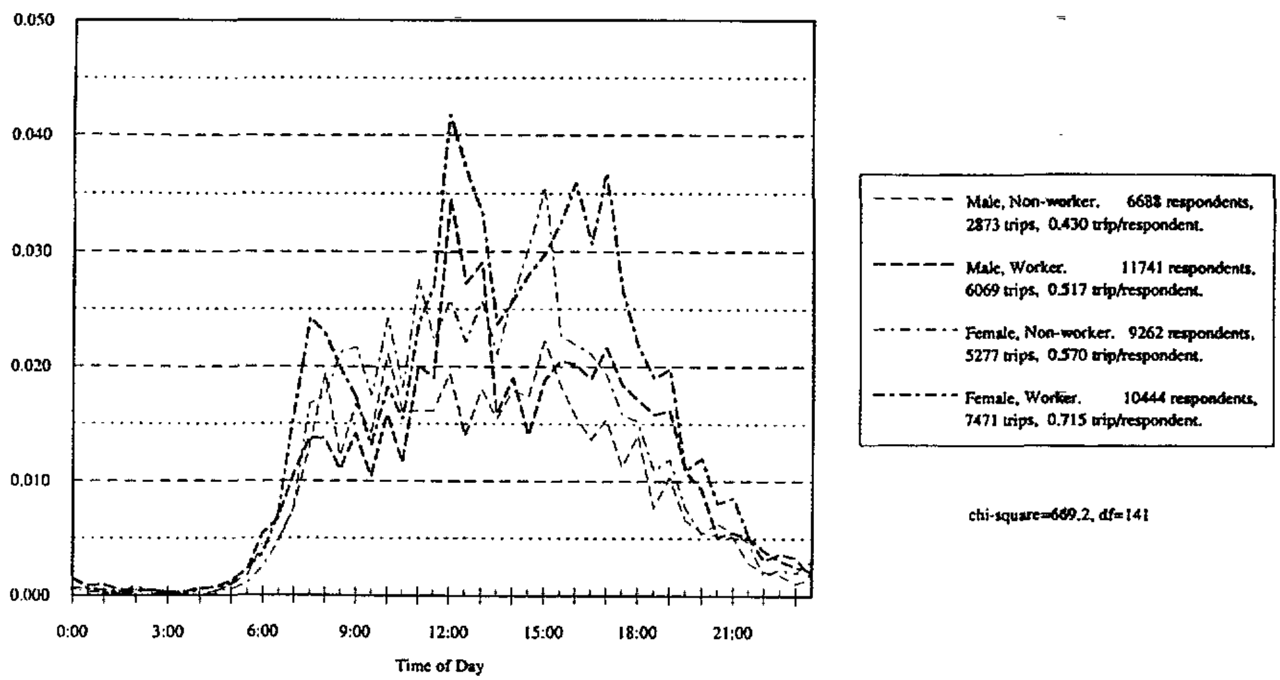

Figure 3.4.d Distribution of Trip Starting Times by Role: Other family or personal business

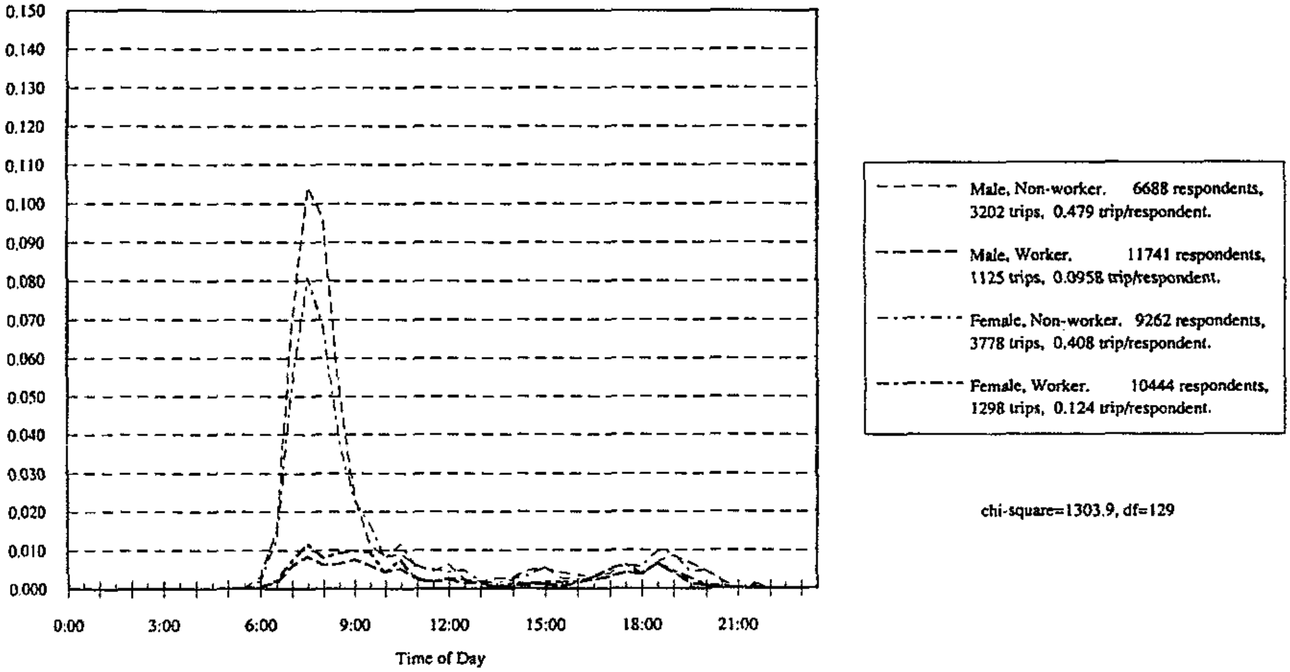

Figure 3.4.e Distribution of Trip Starting Times by Role: School/church

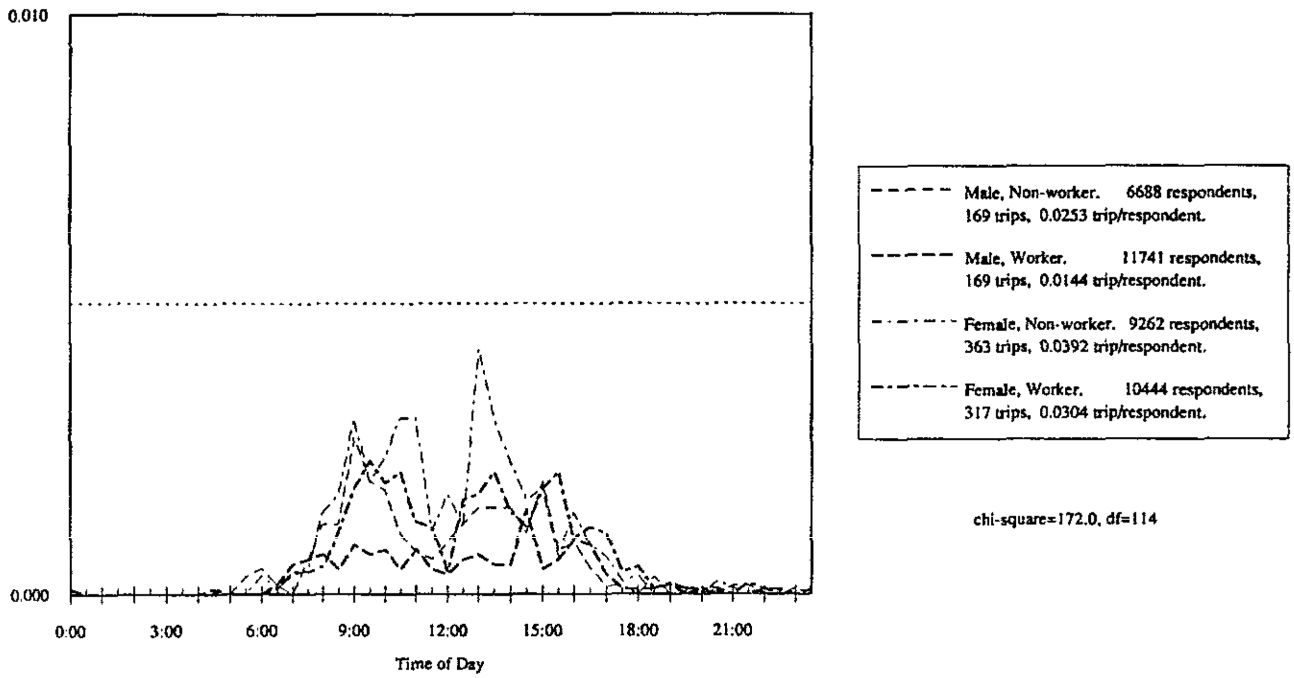

Figure 3.4.f Distribution of Trip Starting Times by Role: Doctor/dentist

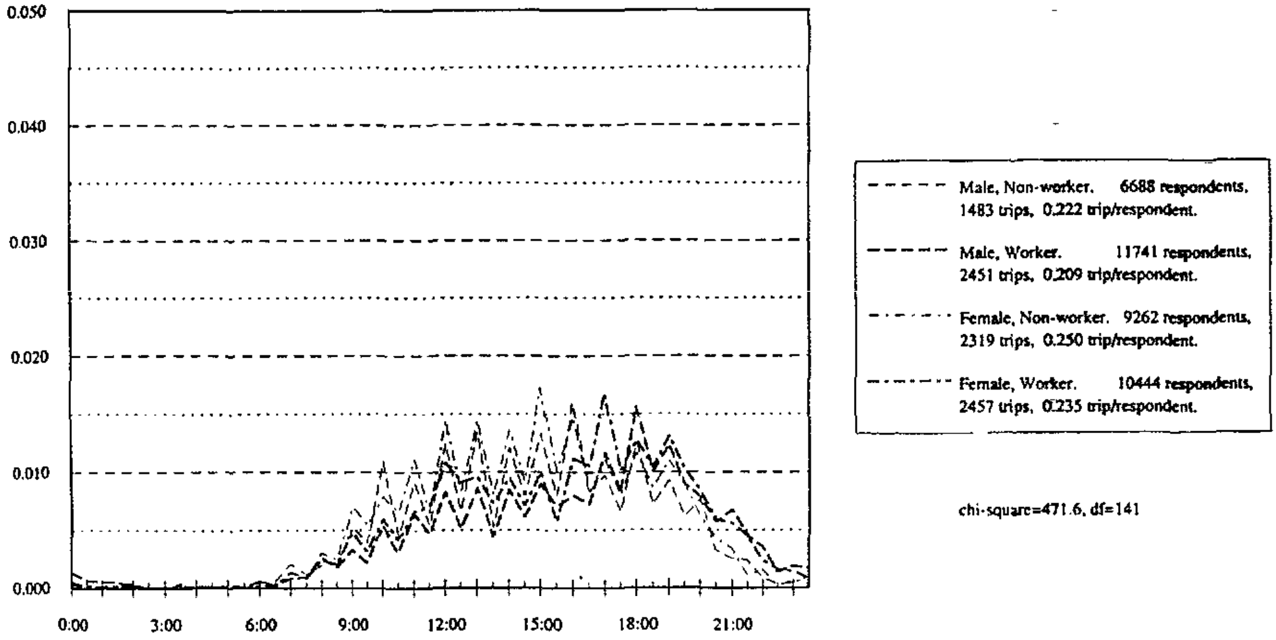

Figure 3.4.g Distribution of Trip Starting Times by Role: Visit friends or relatives

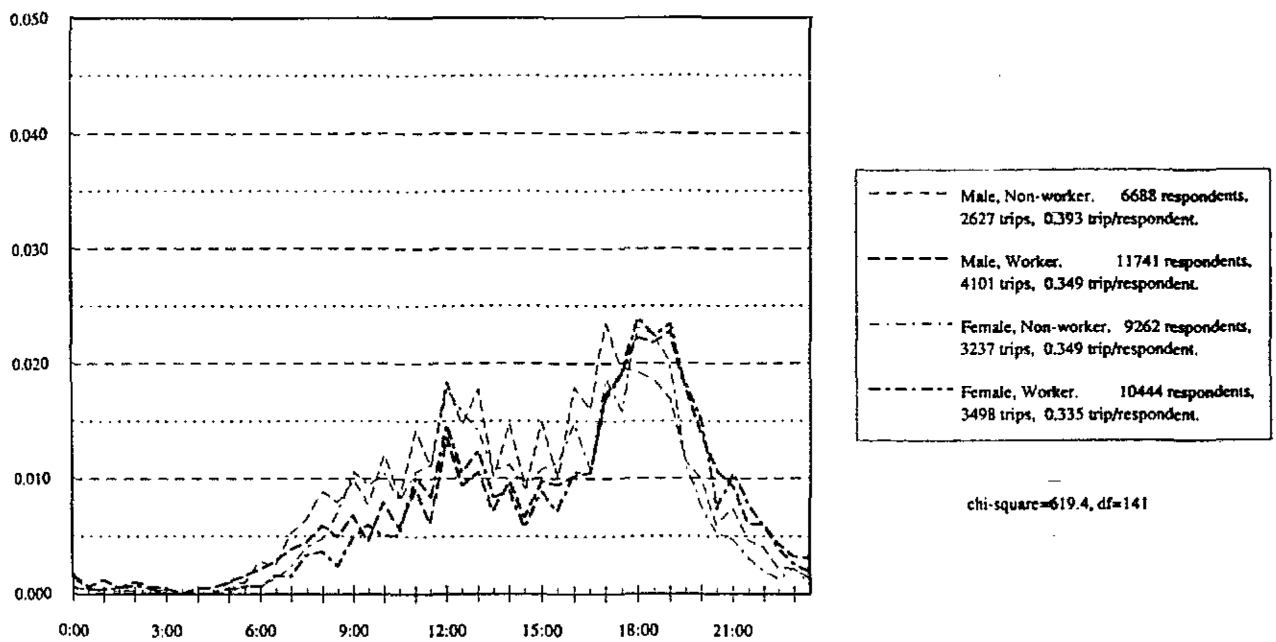

Figure 3.4.h Distribution of Trip Starting Times by Role: Other social or recreational

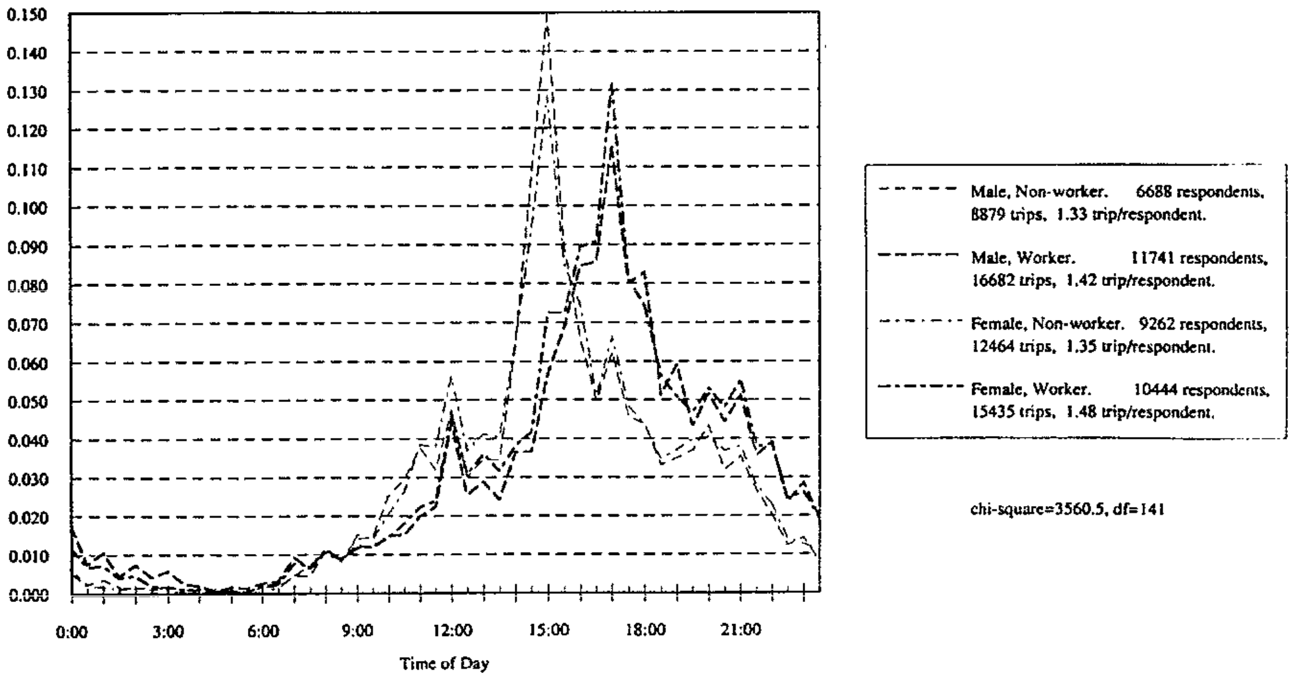

Figure 3.4.i Distribution of Trip Starting Times by Role: To home

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.

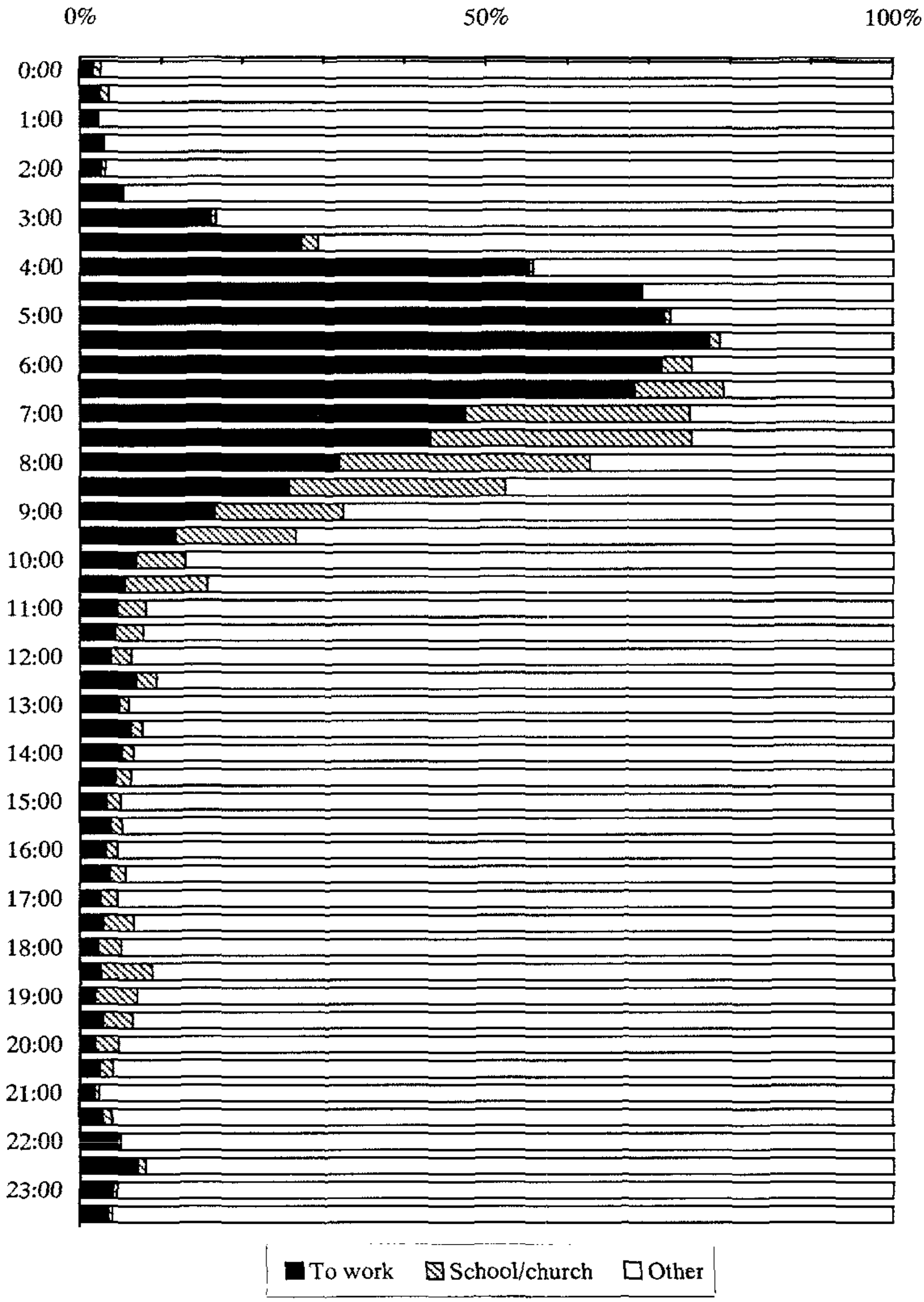

Figure 4.1* Distribution of Trip Purposes by Starting Times

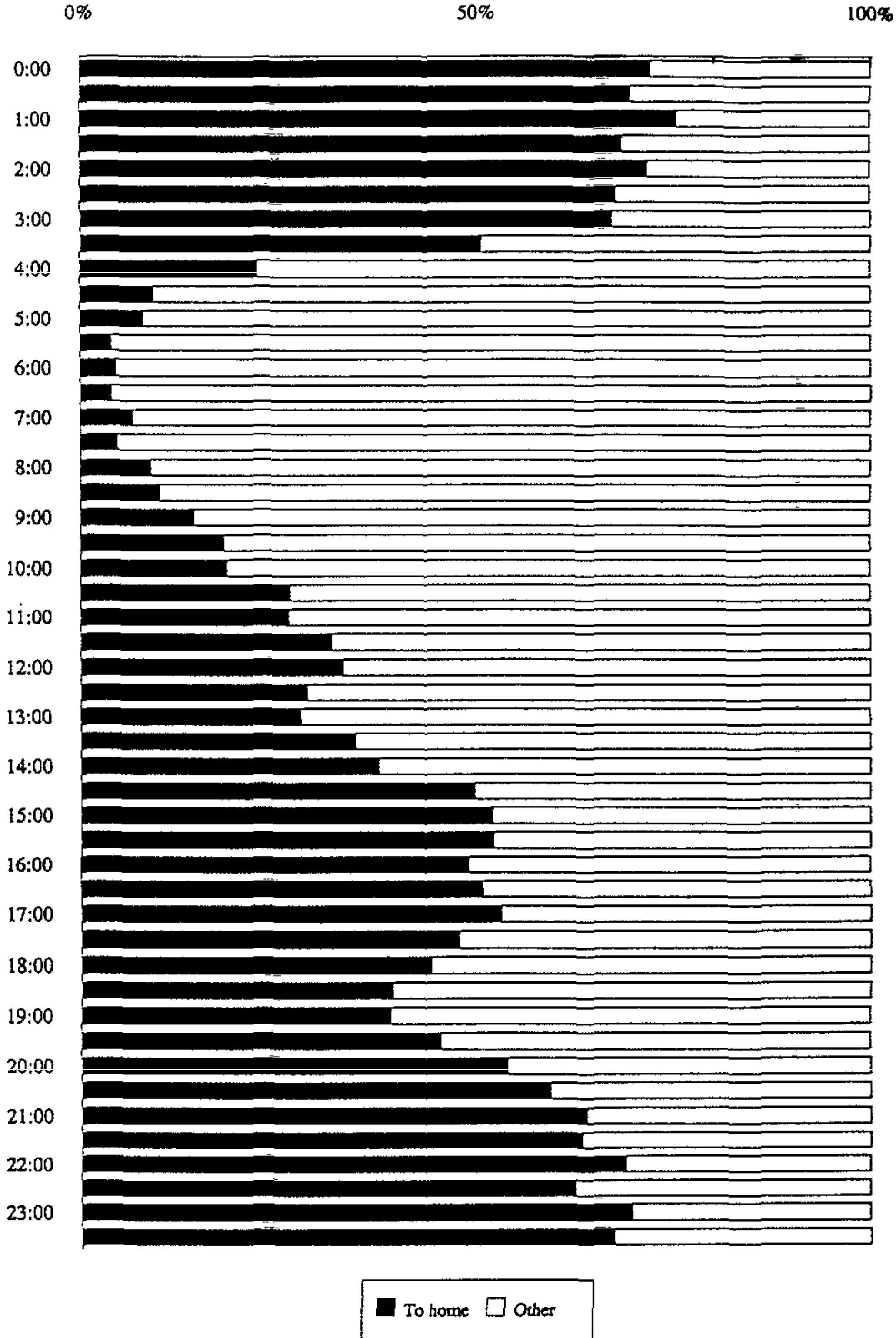

Figure 4.1* Distribution of Trip Purposes by Starting Times

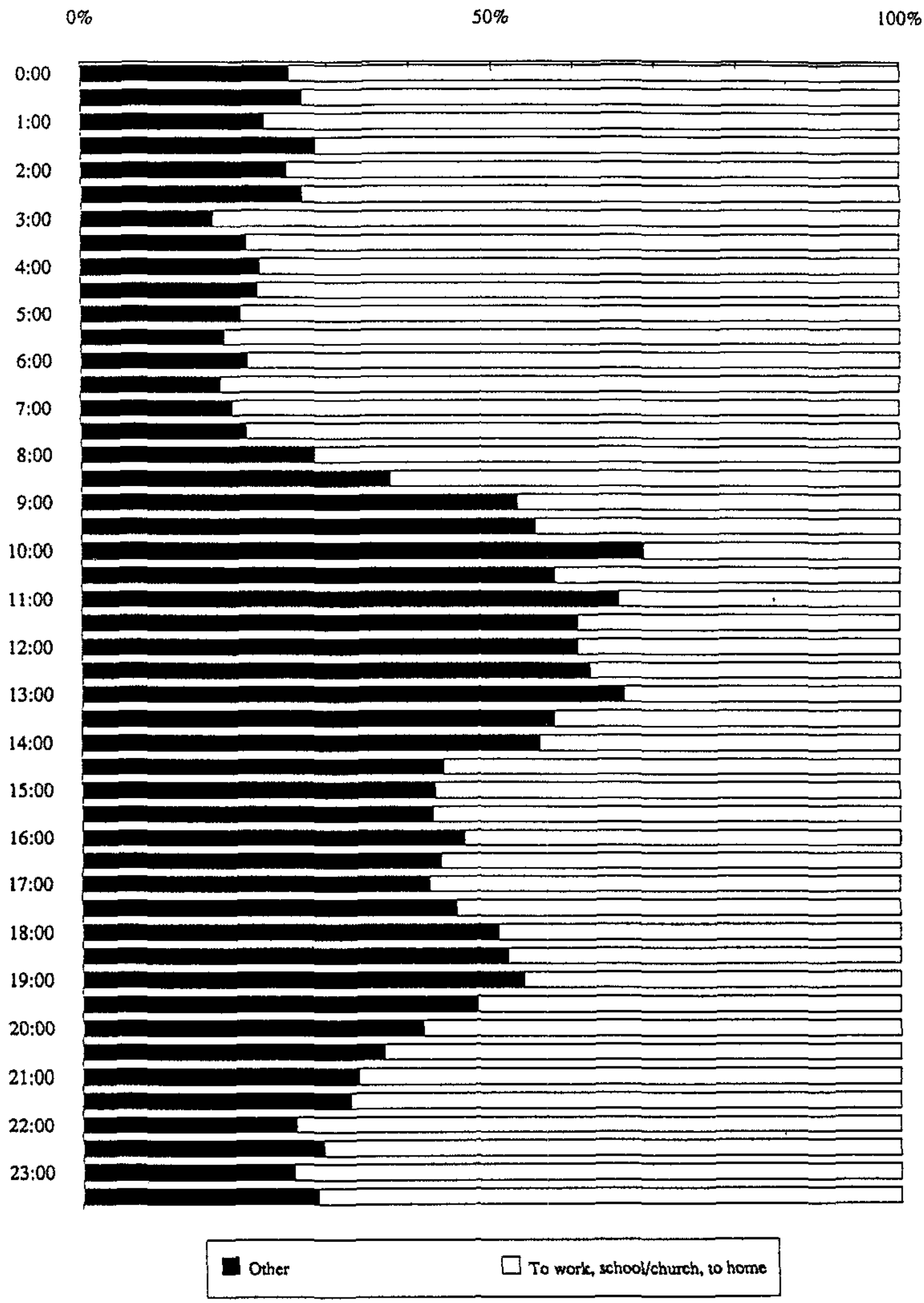

Figure 4.1* Distribution of Trip Purposes by Starting Times

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

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[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

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

$$T_i = \begin{cases} -1 & \text{if } T^*i \leq 0; \\ 1 & \text{if } T^*_i > 0 \end{cases}$$

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

Duration-Timing Model System

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

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

$$T_i = \begin{cases} -1 & \text{if } T^*_i \leq 0; \\ 1 & \text{if } T^*_i > 0 \end{cases}$$

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-

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[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 (σ_{TD}^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 Coef.	Timing Model t	Duration Model Coef.	Duration Model 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.

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Appendix Tables

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

	16 - 24		25 - 34		35 - 49		50 - 64		≥ 65		Total	
Purpose	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 No.	Male Rate	Female No.	Female Rate	Total No.	Total 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 No.	Male Rate	Female No.	Female Rate	Total No.	Total 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 No.	Male, Non-worker Rate	Male, Worker No.	Male, Worker Rate	Female, Non-worker No.	Female, Non-worker Rate	Female, Worker No.	Female, Worker Rate	Total No.	Total 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	

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