TRAVEL IMPACTS OF URBAN FORM: IMPLICATIONS FROM AN ANALYSIS OF TWO SEATTLE AREA TRAVEL DIARIES

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INTRODUCTION

Purpose of Research

Over the past 30 years, a notable change in land use has been the growth of residentially oriented suburban neighborhoods located some distance from employment and service centers. Linked with this growth are increasing levels of traffic congestion, air pollution, and general disenchantment with suburban life (Downs 1992; Langdon 1994). These negative impacts have focused on the potential transportation benefits of traditional oriented neighborhoods characterized by more diverse land use development patterns (Bookout 1992a, 1992b). Developers and planners have suggested that mixing land uses can reduce automobile dependency by making more goods and services available within walking and short driving distances. The new interest in mixed land use represents an about-face with regard to the basic assumptions that have shaped urban development patterns over the past 20 or 30 years.

While interest in mixed-use development is on the rise, only a handful of studies have explored the transportation implications of this type of development empirically. Existing studies typically contain only general information on the demographic characteristics and travel patterns of inhabitants of mixed-use areas. This research seeks to address at least part of this gap in the literature. The researchers used a two-day travel diary and demographic survey of 900 households in three greater Seattle area neighborhoods characterized by two or more distinct land uses. This detailed data set was then compared with similar household travel data collected by the Puget Sound Regional Council (PSRC). Both data sets used similar survey forms and were collected and

coded by the same contractor. The data were compared to see whether the travel behavior of residents of mixed-use neighborhoods differed significantly from the travel behavior of residents in neighborhoods with more homogenous land use patterns.

One goal of the research described herein was to explore whether people in neighborhoods that provide goods and services travel less than people in other more homogenous neighborhoods. This study, unlike previous research on mixed-use, approached this question using detailed, empirical travel data collected *specifically* to explore the travel characteristics of mixed-use neighborhood residents. The travel data were designed to be compatible with similarly detailed regional level travel survey data from the PSRC. This effort resulted in the ability to compare and contrast the travel patterns of mixed-use neighborhoods to other areas.

In addition to the above comparisons, a second goal of this research was to explore the nature of weekend travel in the mixed-use neighborhoods through a variety of measures.

Analysis

This research had two major elements, the first of which was a county comparison of **weekday travel**. Insofar as the mixed-use travel survey was designed to be compatible with the PSRC county level survey (PSRC's survey was for four counties, this research only needed King County), it was possible to explore the differences in travel characteristics between non-mixed-use areas and mixed-use areas by comparing the PSRC's county level data with the neighborhood data.

The second element of this research was a descriptive examination of **weekend travel.** The mixed-use data used for the weekday research also collected travel information for weekends. Because weekend travel is little studied, the mixed-use survey results provided a welcome opportunity to consider this travel behavior separately.

Both elements of this research considered the following categories of analysis: travel times and distances, demographics, multi-purpose trips, and intra-neighborhood analysis.

Travel Times and Distances. The use of transportation modeling output, Geographic Information Systems (GIS) software (TransCAD), and a U.S. Census-derived computer file of the county street network allowed for calculation of a number of important spatially-oriented travel statistics. Most relevant was the ability to estimate respondents' trip mileage in the mixed-use neighborhoods, both individually and as households, from original survey data by estimating travel routes on the street network. The travel distance procedures also provided the ability to accurately calculate short trip distances. Travel times were reported directly in both data sets and provide valuable information.

Demographics. Household and individual demographic characteristics were compiled to identify possible correlation with observed travel patterns in each of the study neighborhoods.

Multi-Purpose Trips. Many people schedule their activities by combining several trips into a single, sustained journey or chain. Analyzing the number, length, and type of chains, as well as the characteristics of the trip maker, sheds light on how travel is organized for efficiency, especially around work trips.

Intra-Neighborhood Analysis. Each of the three mixed-use neighborhoods encompassed concentrations of retail and other service establishments. This research examined the travel patterns of households at various distances such concentrations, and explored the extent to which proximity to commercial outlets and services affected the mode choice other than the auto—and in particular, whether walk trips replaced vehicle trips for short-distance travel.

Analysis Limitations

This analysis is limited in several respects. Since the research is based on survey data, it is possible that some variation in travel behavior is attributable to self-selection by certain types of individuals in different neighborhoods. It is difficult to measure this type of bias.

The research also compares the PSRC panel survey data with the mixed-use neighborhood data. While the research designs for the projects were similar, the two surveys were conducted two years apart, increasing the possibility of some incompatibility between the data sets. Additional incompatibility may result because the PSRC data were collected September through December, while the mixed-use data were collected only in November and December. As a result, the mixed-use data could be biased toward shopping trips because of the increase of retail activity during the Christmas season. The two data collection efforts also used slightly different sampling procedures, and the mixed-use survey form was more comprehensive, resulting in other possible limitations when comparing across data sets.

The PSRC panel survey instructions requested that the participants report all trips five minutes or longer. Since pedestrian, bicycle and short vehicle trips are important in studying mixed-use neighborhoods, the mixed-use data instruction requested that all trips be included. In spite of this difference in instruction, both data sets include similar percentages of trips less than five minutes long. The mixed-use data included 7.0 percent of the trips less than five minutes, while the PSRC data set had 6.5 percent of all trips. However, for the most accuracy, when possible, any comparison between the two data sets removed all trips under five minutes in length.

The PSRC panel data and the mixed-use data both constituted two-day travel diaries. Naturally, travel on one of the two days is not independent of the other; nor, for that that matter, are trips within a single day independent for a given person or between people. While this may cause problems for some types of analysis and for developing travel models, this study is merely comparing similar households across various types of geographic areas.

Report Structure

The remainder of this paper is divided into six sections.

Literature Review. The research literature concerning empirically oriented analyses of neighborhoods with mixed-use characteristics is reviewed, identifying the scarcity of quantitative analyses of neighborhood travel behavior, particularly as they relate to land use. The few empirical studies on weekend travel are also covered.

The Data Sets. This section discusses the two data sets used for the study. First, a brief review of the data collection methodology is given. Since the subsequent analysis of the data set requires specific knowledge of trip locations (origin and destination), the process by which those locations were derived from the survey responses and coded (i.e., the geocoding process) is discussed. The PSRC data set used for regional comparisons is also discussed. This discussion concludes with a comparison of the mixed-use and PSRC data sets; several key differences between the data sets are highlighted.

Research Methods. This chapter reviews the techniques and issues associated with processing and preparing the data for computer analysis.

Data Analysis — Weekdays. The mixed-use data and the panel survey data are analyzed statistically and spatially. The major findings from the comparison of these data sets are then discussed and compared with those of other studies.

Data Analysis — Weekends Travel in the mixed use neighborhoods for weekends is analyzed and numerous descriptive statistic regarding weekend travel are presented. General travel characteristics, day and time variations, as well as a separate look at walking trips provide insight into the weekend travel patterns of the mixed land use neighborhood residents.

Summary and Future Research. The results of this research are summarized and the conclusions are presented.

LITERATURE REVIEW: TRAVEL IN MIXED-USE NEIGHBORHOODS WEEKDAYS AND WEEKENDS

General Travel

The **Nationwide Personal Transportation Survey (NPTS)** is a randomly sampled telephone survey collected every few years designed to provide a comprehensive look at personal travel in the United States. The 1990 survey and the three earlier surveys provide data (although no origin and destination data) useful in examining the relationship among demographic, land use, and transportation changes. The following three summaries are from studies that utilize these data.

According to **Comsis** (1994) vehicle miles of travel (VMT) increased nationwide by 37 percent between 1983 and 1990, although the population only increased by 4 percent. The report indicated that higher residential and employment densities can promote less reliance on private

vehicle trip making: "Persons residing inside the central cities of urbanized areas make more shorter trips than persons living outside central cities."

Pisarski (1992) used the weekday data from the Nationwide Personal Transportation Survey (NPTS) and found that "the geographic distribution of population is far more crucial than population growth in creating dramatic changes in travel in individual locations." He indicated that one of the most significant factors in trip growth is the population shift to large metropolitan areas, and subsequently to these areas' suburbs.

Gordon and Richardson (1994) published another NPTS-based study. They sought to explain changes in work trip length and determined that although trip lengths have increased, so have travel speeds. Their findings support the view that suburbanization allows people to live farther from activity centers at a modest marginal cost in terms of extra time traveled, due to higher speeds. In contrast to almost every other researcher, they conclude that "urban sprawl is a transportation solution, not a problem."

Trip Characteristics and Travel Patterns of Suburban Residents by **Prevedouros and Schofer** (1991) analyzed weekday travel behavior based on a 1989 mail-back survey of individuals residing in selected Chicago suburbs. One of four factors analyzed were two classes of suburbs: inner-ring, high density, stable suburbs; and outer-ring, low-density, growing suburbs. Key general findings indicated that residence location in outer-ring suburbs implies longer trips and more frequent local trips. Although the average travel speed by automobile is higher for residents of growing suburbs, they still stay in traffic 25 percent longer and have a 40 percent longer total daily distance compared with stable-suburb residents.

In a more general study, the **Puget Sound Council of Governments (PSCOG)** published a report in 1990 on household travel surveys from the counties in the Seattle metropolitan area. One- to three-day travel diaries were collected from 4,500 households between 1985 and 1988. The survey's purpose was to update earlier survey research for use in travel demand forecasting and planning. Results indicated that while household size is decreasing, the smaller households have more vehicles. The surveys confirmed that trip making per person and per household have increased substantially (**Table 1**) and that nearly 90 percent of all trips are made by private vehicle. Average vehicle occupancy in the region declined from 1.25 persons per vehicle in 1961 to 1.1 in 1987.

Table 1. Person Trips in Puget Sound Region

Year	**Average Number of Person Trips per Person in Puget Sound Region**
1971	2.6
1987	4.3

source: PSCOG 1990

Summary of General Travel

Empirically based travel studies generally indicate that travel is increasing, and that residents outside the central city travel longer and farther, although at higher speeds, than inner ring residents (**Table 2**).

Travel in Mixed-Use Neighborhoods

After studying southern California, **Giuliano** (1995) contended that the connection between land use and transportation is negligible because urban areas in the U.S. are already so accessible, because settlement patterns are well-established, and because privacy is so important to most people. As such, transportation plays an ever-decreasing role in the locational decisions of households and businesses. Her essay implies that the land-use transportation connection is too weak to provide of public policy direction.

Cevero and Landis (1995) rebutted Giuliano's article. Although they agreed that the connection is much weaker today than a century ago, they argued that the relationship remains important. In support of this view, they cited studies showing how land prices have gone up around new transit stations and commute trips that tend to be shorter for those living in areas with balanced housing and jobs. They conclude that land use can be an important contributor to transportation trends and vice versa. The authors expressed belief that, in the land use-transportation connection, considerable elasticity remains.

Another study to examine the land use connection to transportation was **Frank and Pivo** (1994), the first in a series of projects seeking to identify which land-use patterns reduce auto use. The authors studied 1989 travel in the greater Seattle/Tacoma region and found that commute distances and times tended to be shorter for those inhabitants of balanced areas. More specifically, the average length of work trips ending in a balanced census tract was 29 percent shorter than work trips that end in unbalanced areas (**Table 3**).

Table 2. Summary of General Travel Studies

Author	Key Findings
Comsis	Travel increasing due to increased trip frequency and length higher densities and living inside central cities promote shorter trips
Pisarski	Geographic distribution of population is more important than population growth in travel patterns changes.
Gordon et al.	General travel trends indicate longer trip lengths but also higher travel speeds
Prevedouros et al.	Outer ring growing suburb residents make 40 percent longer trips (but have higher travel speeds), spend 25 percent more time in the car, and make more frequent local trips than residents from inner ring stable suburbs.
PSCOG	Household size and vehicle occupancy decreasing, while there are more vehicles per households, and more trips per person.

Table 3. Work Trip Length in Puget Sound Area

Balance of Census Tract where Work Trip Ends (jobs to household ratios)	Distance of Work Trip (miles)
Balanced area (ratio = 0.8 — 1.2)	6.9
Unbalanced area (ratio < 0.8 or > 1.2)	9.6

source: Frank and Pivo 1994

In a later study, **Pivo** et al. (1995) examined the market for less auto dependent land use by studying 1970 - 1990 data on the population density, housing density, employment density, jobs-housing balance, and retail-housing balance of both metropolitan cities and unincorporated areas in Washington state. Through examination and comparison of statistical distributions, relationships between land use variables were found, and associations between both density and balance and less auto use were confirmed. The report recommended promoting greater density and balance to communities whose land-use patterns are capable of supporting greater transit use and less out-commuting.

In 1992, a series of articles by **Bookout** in *Urban Land* explored neotraditional development. In the first article (Bookout 1992a) the author argued that the 45 percent of the population that moved to the suburbs after World War II never really realized the American dream due to traffic snarls, inadequate social services, etc. One of the major flaws with the suburban vision is excessive travel needs brought on by low-density development. The author recommended neotraditional communities, with (among other things) more through streets instead of cul-de-sacs, to give drivers alternate routes between points, which may result in shorter and less congested travel.

A second article, "Cars, Pedestrians, and Transit" (**Bookout** 1992b), asked whether people must continue to drive between each and every one of the places they visit regularly. The author suggested that with the building of more neotraditional communities, the answer should be "no." He advocated three items to reduce either the number of vehicle trips or trip distances:

1. A return to the grid pattern for streets, or at least an effort to provide more direct connections between any two points within a community.

2. Communities that are pedestrian and bicycle friendly.

3. Increased transit viability.

Bookout cited Kulash's study (1990) to substantiate his recommendations. **Kulash's** study used simulation modeling to compare the traffic patterns of developments with densely gridded streets (called "traditional neighborhoods" but referred to as "neotraditional" by most authors and in the remainder of the paper) to communities with partially connected streets and cul-de-sacs (called "conventional suburban developments"). The author analyzed the travel performance of the theoretical developments and found that a traditional neighborhood design could produce fewer total vehicles miles traveled than a comparable conventional suburb (although much higher travel on local streets) (**Table 4**). Traditional neighborhoods did have lower travel speeds, but trips were also shorter. He concluded that traditional street networks function more efficiently than do conventional networks. However, this study did not measure trips beginning or ending outside the community. Nor did he indicate whether a traditional development would actually generate fewer trips than a conventional development.

McNally and Ryan (1993) used modeling to explore potential transportation benefits of neotraditional neighborhood design. They compared the traffic performance of a conventional suburb (with a hierarchical street network) to that of a neotraditional community (with highly connected gridded streets). All aspects of the theoretical neighborhood including land use, were held constant except for the actual configuration of the networks. The models indicated 10 percent fewer vehicle-kilometers traveled in the neotraditional network for the same level of trip generation. Total vehicle-hours traveled in the neotraditional network were reduced by 27 percent and the average trip lengths were 15

Table 4. Vehicle Miles of Travel in Theoretical Communities

Vehicle Miles of Travel (internal travel only)	Difference Between Traditional Development (TND) and Conventional Suburb (CSD)
Arterial Streets	TND is 25% of CSD
Collector Streets	TND is 15 % of CSD
Local Streets	TND is 400% of CSD
Total Vehicle Miles Traveled	TND is 57% of CSD

source: Kulash 1990

percent shorter than in the conventional network. The authors concluded that with the same level of activity, neotraditional networks operate more effectively, experience less congestion, and require less travel than conventional networks. They also indicated the drivers in neotraditional networks may choose more direct routes.

Friedman, Gordon, and Peers (1992) compared 1980 travel data from traditional communities to suburban tract developments in the San Francisco bay area in order to investigate any differences in trip generation and mode choice. The older communities developed prior to World War II had gridded street networks and were characterized by a mixture of residential and non-residential uses. In contrast, the suburban developments tended to contain many cul-de-sacs and segregated land use, and a hierarchical roadway. In order to control for income differences, the wealthiest and poorest households in each neighborhood were eliminated from the study. The results, which provide a basis for measurement of the potential impacts of different land use patterns, showed that suburban areas generated 23 percent more trips, had higher drive alone rates (68 percent in suburban neighborhoods versus 49 percent in traditional communities), and had half the transit share of traditional communities. The authors concluded that traditional neighborhoods have characteristics that result in fewer automobile trips than do newer suburban developments.

Although the Friedman et al. study is widely cited as "proof" of mixed-use neighborhood transportation advantages, others counter that it is impossible to separate out the relative importance of the many differences between suburban and traditional communities. **Crane** (1996), for example, praised neotraditional town planning for its thoughtful and functional design, but he questioned its actual transportation benefits. He pointed out that transportation problems may, in fact, worsen—while it is likely that many elements of the new designs discourage driving for some kinds of trips, the aggregate effect is uncertain. Here's why:

The rectilinear grid street pattern is the easiest transportation feature to implement in neotraditional town planning and is widely encourage by many observers (e.g., Kulash, McNally, and Ryan). However, these authors assumed that trip frequencies are fixed; they never analyzed the

potential change in demand for trips due to the new street pattern. Crane agreed that the grid pattern creates more access and thus shorter average trips than a cul-de-sac pattern. However, he countered that the increased access reduces the cost of travel, thus encouraging people to take *more* trips. He concluded that a change in street configuration may or may not reduce auto travel, that the transportation benefits of neotraditional designs have been oversold, and that each development must be evaluated on a case-by-case basis to predict the net use.

Another study skeptical of the supposed transportation advantages of mixed land use is **Kitamura, Mokhtarian and Laidet** (1994). This study used travel diaries and attitude surveys to explore travel behavior in five diverse neighborhoods in the San Francisco area. Initially they showed that neighborhood characteristics were significantly related to travel behavior. Measures associated with lower rates of travel included higher residential density and more mixed land use. The next step of the study attempted to demonstrate that attitude, not land use, was the primary determinant of travel behavior. By showing that attitudes were more strongly correlated to travel behavior than neighborhood characteristics, the authors argued that the land-use - travel relationship was an artifact of an association between land-use and variety of social and demographic characteristics associated with travel. They suggested that land-use determined attitudes; higher density, for example, means smaller houses, lower incomes and other factors that affected one's attitude. Attitude in turn influenced travel behavior. The authors concluded that land-use policies promoting high densities and more mixed use may not influence travel behavior unless residents' attitudes are also changed.

A study centered around household based trip statistics is by **Holtzclaw** (1991), who studied data from several types of communities with varying densities and land use mixes in the San Francisco region. Odometer readings and trip logs were used to determine reduction in automobile mileage due to higher residential density, neighborhood businesses, and improved transit service. The conclusion is that as the housing, population, and commercial densities decrease, and the transit service decreases, the vehicles miles traveled (VMT) per capita and per household increase. Doubling residential or population density reduces the annual auto mileage per capita or per household by 20 to 30 percent.

A detailed travel survey study was documented by **Ewing et al.** in 1994. Six communities in Palm Beach County, Florida, were chosen for study based on their diverse development. Household travel data including trip frequency, mode choice, trip chaining, trip length, and overall vehicular travel were used to study the relationship between household travel, location and land use. The researchers concluded that households in the "sprawling" non-gridded suburban community (composed mainly of single-family homes) had almost 66 percent more vehicle-hours than did a traditional gridded community with varied land use. Other communities fell between the extremes. The authors concluded that higher density, mixed land use, and central location tended to be associated with reduced vehicle-hours of travel.

An article that encouraged further research was by **Steiner** (1994). This study documented literature on residential density and travel patterns. The author concluded that decreased usage of the automobile is possible in higher-density residential areas because of several factors:

1. High density puts destinations close together, making it possible to walk.

2. The greater number of people in an areas, the more an area is perceived to be safe for walking.

3. Certain types of people and households may be more likely to live in high density residential areas.

However, like Crane, Steiner cautioned that often assumptions are made concerning the relationship between high-density neighborhoods and the residents' transportation choices which may or may not be true. She indicated that many studies have not separated out factors such as income, household size, life-cycle characteristics, etc., which also affect transportation choices. Steiner advocated further research to sort out the importance of the pattern of travel based on the above characteristics; only then can conclusions be drawn on which households might be willing to live in high-density areas and the extent to which changes in land-use patterns reduces travel.

Handy in a 1991 article summarized the issues surrounding the concept of travel in mixed-use neighborhoods. Proponents claim fewer and shorter auto trips, more walking trips, and a greater sense of community in these developments. Yet critics and skeptics indicate these claims are not proven, that people may not want to live in these neighborhoods, and that the entire concept is simply not feasible. The author articulated a need to answer the underlying question of how neotraditional developments will relate to the larger settlement patterns. She concluded that the entire debate over the neotraditional issue "is greatly in need of substantive arguments, of testing and exploration of issues at a much greater depth than has occurred to date."

Summary of Travel in Mixed Use Neighborhoods

All of the studies in the above section detail travel in mixed-use neighborhoods. **Table 5** summarizes the key findings for each study and identifies relevant items to the research in this paper.

Most of these studies find some sort of association between mixed-use neighborhoods and less auto travel. However, some authors (e.g., Kitamura; Crane; Steiner; and Handy) urge caution because the issue is complex. They contend that studies need to carefully factor out household and life-cycle characteristics before relevant comparisons can be made.

Weekend Travel

Weekend travel in the Puget Sound region was the topic of a 1971 PSCG report which indicated that "there is increasing concern that proper attention has not been given to recreational travel (primarily done on the weekends) as a factor in transportation planning." The study proposed a multi-phased concept for long-range planning of urban transportation facilities to serve the weekend travel demands of metropolitan areas. Recommended methods included a variety of modeling (due to limited availability of empirical data). The study did not report any results and only travel to major recreational areas were addressed.

A recent study from Japan (**Yai et al.** 1995) indicates that the volume of passenger vehicles for recreational traffic on weekends can be equivalent to that of weekday commuter traffic. This study, like the previous one, will develop recreational travel demand models. It will be used for trip generation and trip distribution using an aggregate regression model and a disaggregate model.

Voorhees and Associates (1974) also proposed modeling to analyze weekend vehicular travel. The scope of the study was Sunday afternoon traffic on rural highways returning from recreational destinations to urban areas. Some state and national data were used to calibrate the model, some output of which shown in **Table 6**. The authors concluded that weekend travel demand must be linked with weekday travel estimates for adequate highway design. They added that any "model is only as good as the input data. Therefore, a large amount of empirically derived data is necessary to simulate present travel patterns." They cautioned that good travel data for weekend analysis is lacking in many state planning agencies.

A more recent study on vacation travel was entitled "Weekend Travel: America's Growing Trend" (**US Travel Data Center** 1990). Its focus was for round trips of at least 200 miles, multiple day (one to five night) trips taken over a weekend. Although geared toward the travel industry, some findings are illustrative of weekend travel in general. Information was obtained from the Data Center's National Travel Survey and indicated that between 1984 and 1989 total trips increased by 26 percent, while weekend trips increased by 34 percent. **Table 7** shows trip characteristics and demographics for weekend vacation travel.

An empirical study exploring weekend traffic volumes was done in the Santa Monica Mountain area of southern California (**City of Los Angeles** 1978). Although most of the results are specific to that area (e.g., volume percentages for certain intersection approaches), this study introduced the concept of temporal distribution. The study demonstrated that both Saturday versus Sunday and time of day distributions would be interesting variables to explore.

Hu (1996) used the Nationwide Personal Transportation Survey for a study on travel behavior by day of week. Multitudes of figures and tables describe household characteristics, person characteristics, and trip characteristics for Saturday and Sunday travel. This information can serve as a benchmark for weekend travel in typical urban areas.

Table 5. Summary of Travel Studies on Mixed Use Neighborhoods

Author	Key Findings	Relevant Notes
Giuliano	Land use — transportation connection too weak to matter in terms of public policy	Based primarily on commuting research
Cevero and Landis	Land use can be important contributor to transportation trends.	Includes research on rail transit
Frank and Pivo	Average work trip length ending in a balanced area 29 percent shorter than work trips that end in unbalanced areas	
Pivo et al	Association between both density and balance and less auto use confirmed	
Bookout	Fewer cul-de-sacs, return to grid street pattern, and ped. and transit friendly neighborhoods will reduce vehicle trips or trip distances	Based on Kulash Study
Kulash	Traditional street network produces 57% less total VMT, shorter trips and works more efficiently than conventional suburb	Internal trips only, trip frequencies are fixed and local street traffic much higher for traditional network
McNally and Ryan	Neotraditional network has 10% less veh.-km and 27% less veh.-hrs traveled, and 15% shorter ave. trip length than conventional network	Trip frequencies are fixed

Table 5. Summary of Travel Studies on Mixed Use Neighborhoods (Continued)

Author	Key Findings	Relevant Notes
Friedman, Gordon and Peers	Suburban areas generated 23 % more trips, had higher drive alone rates and had half the transit share of traditional communities	
Crane	Contradicts Kulash, McNally and Friedman. Says one cannot separate out many differences between suburban and traditional communities. Transportation problems may worsen in traditional communities because trip demand may go up. Therefore trip frequencies in network studies should not be fixed.	
Kitamura et al.	Land policies promoting high densities and more mixed land use may not influence travel behavior unless resident's attitudes were also changed.	
Holtzclaw	Doubling residential or population density reduces the annual auto mileage by 20 to 30%	Did not correct for income
Ewing	Households in suburban community had 2/3 more veh.-hrs than a traditional community with gridded streets and varied land use.	Controlled for income & included chaining analysis
Steiner	Higher density residential areas make decreased usage of auto possible. Household and life -cycle characteristics need to be factored out	Advocates further research
Handy	Need to answer how mixed use developments will relate to larger settlement patterns	Advocates more research

Table 6. Weekend Travel Characteristics

Topic	Finding
Primary Weekend Trip Purposes:	Recreation: 33 % Social: 34 % Shopping: 10%
Average Trip Lengths:	70-100% longer for weekend trips than for weekday non-work trips

source: Voorhees and Associates 1974

Table 7. Weekend Vacation Trips

Topic	Response	Value
Main Purpose of Trip	Visit Friends and Relatives Outdoor Recreation and Entertainment	45 % 45 %
Travel Party Size	One Two Three	41 % 33 % 12 %
Presence of Children	Parties without children Parties with children	78 % 22 %
Income	Less than $35,000 per year More than $35,000 per year	45 % 39 %
Household Structure	Single adult, no children Single adult, with children Two or more adults, no children Two or more adults, with children	19 % 4 % 40 % 37 %
Household Size	One Two Three Four Five or more	19 % 29 % 22 % 19 % 10 %
Age	Average	39 years
Sex	Male Female	51 % 49 %

source: US Travel Data Center 1990

Finally, some useful weekend travel data for this project were obtained from **Murakami (**1996) who used data from the Nationwide Personal Transportation Survey. Several tables listing weekday travel were redone for weekend travel only and served as an excellent reference for the research summarized in this paper. **Table 8** shows general information about the three variables used in this research.

Summary of Weekend Travel

Table 9 shows the major findings of weekend travel studies. The focus is mostly on long distance recreational travel not influenced by urban form. Hu and Murakami will serve as excellent

base points from which to compare the characteristics of typical urban areas with those of mixed use neighborhoods. However, none of these studies addressed the issue of walking trips.

Literature Review Summary

This literature review has shown that travel is increasing, and that mixed-use neighborhoods may offer some transportation benefits. Many of these studies have shown that mixed-use or neotraditional neighborhoods are associated with less auto travel.

On the other hand, several authors urge caution and more research because of the issue's complexity. Household and life-cycle characteristics need to be carefully factored out before relevant comparisons can be made between mixed-use neighborhoods and more suburban areas. Additional measures such as trip frequency and travel speed must be analyzed to portray travel patterns.

Non-work travel is gaining in magnitude and complexity. Trip chains are becoming increasingly important, and trip counting techniques (such as number of trips) must be modified to reflect the new transportation trends more accurately. Short walking trips are important in non-work travel in mixed-use neighborhoods, as such, they should be included in the analysis.

Finally, weekend travel is an area that has received little research attention. Most modeling studies suffer from a lack of data upon which to calibrate the models. Extant empirical studies have not addressed mixed-use neighborhoods explicitly (including short walking trips).

THE DATA SETS

Introduction

This research was based on two data sets. First, a mixed-use neighborhood data set was collected by the Washington State Transportation Commission's Innovations Unit in November and December of 1991 as part of this study. Second, the Puget Sound Regional Transportation Panel Survey, conducted from September through November 1989 and obtained from the PSRC, was used as a reference data set. To enhance the validity of comparisons between the two data sets, the mixed-use data collection effort was designed for compatibility with the PSRC's panel survey methodology.

While this section focuses on the data collected from the mixed-use neighborhoods, the data collection methodology for both data sets is discussed briefly. The mixed-use data required considerable preparation for analysis, and the steps of this process are documented herein. Since both data sets are compared, differences between the mixed-use data set and PSRC data set are discussed.

Table 8. Data Comparison Topics from Murakami

Table Title	General Information
Average Weekend Trip Length by Purpose	4-18 miles
Average Weekend Trip Length by Mode	0.5-14 miles
Daily Person Trips per Household by Household Size	2-11 trips

source: Murakami 1996

Table 9. Summary of Weekend Travel

Author	Key Findings	Relevant Notes
PSGC, and Yai	Highlight need for weekend travel studies. Propose modeling to study weekend recreational travel demands	No results
Voorhees et al	Primary weekend trip purpose: social, recreation and shopping.	Recommend more empirical studies
US Travel Data Center	Provides trip characteristics and demographics.	Based on longer vacation trips only
City of LA	Not relevant	Use temporal distributions
Hu	Household, person, and trip characteristics listed for more typical urban areas	Good source for data comparison
Murakami	Average trip length by purpose and mode as well as trip frequency given for typical urban areas.	Good source for data comparison

The Mixed-Use Data

The mixed-use neighborhood data set was obtained from a series of two-day travel diaries completed in November 1992. Over 1,620 individuals in 900 households in the Kirkland, Wallingford, and Queen Anne neighborhoods in the greater Seattle region responded. A project report (**Zemotel et al.** 1993) details the data collection methodology, characteristics of the study neighborhoods, and preliminary data analysis.

Neighborhood Descriptions

Neighborhoods were selected for study because they had more than one distinct land use (residential as well as other uses), and because each was located in an area offering a range of mode choices. The location of each neighborhood is shown in **Figure 1**.

Queen Anne, located a few miles north of downtown Seattle, was the smallest of the three study areas. The study area was roughly 0.5 mile by 0.7 mile, centered on Queen Anne Avenue, a busy shopping street with supermarkets, banks, restaurants and retail shops. The rest of the study area was residential with a few scattered retail and office facilities. Queen Anne's streets form a grid pattern.

Wallingford is west of Interstate 5, a few miles north of downtown Seattle, and west of the University of Washington. The study area was approximately 0.75 mile by 1.25 miles long. The neighborhood's land use is diverse with parks, residential uses, and a variety of retail and commercial buildings. The main shopping area is along Northeast 45th Street and, to a lesser extent, along Stoneway Avenue North. The street pattern forms a grid.

Kirkland is a suburban neighborhood bordered by Lake Washington on the west and Interstate-405 on the east. The study area was the largest and was approximately 2.0 miles by 1.2 miles. The area includes a renovated downtown and a mix of housing types. Kirkland's shopping and commercial facilities are somewhat more scattered than those of the other study neighborhoods, but there are concentrations along Central Way and at the downtown 'core' where Central Way meets Lake Street Kirkland has a combination of a grid street pattern and curvilinear streets with cul-de-sacs, which is different from the strictly gridded streets of Wallingford and Queen Anne. Kirkland's land use pattern in many ways represents a transition between a mixed-use area and other suburban development.

Data Collection Process

Individuals in each neighborhood were initially contacted through a random dialing phone survey. First, a range of demographic information was collected from each respondent. This information included the number of vehicles owned, family size, and income. Information was also collected on each person (over the age of 15) surveyed. This information included age, sex, and whether the respondent was employed, a student, or neither. Respondents were then asked to participate in a travel diary survey. Those who agreed to participate were then sent a travel diary packet. Forty-three percent of the people contacted agreed to complete the travel diary. Among this group 76 percent returned a completed diary resulting in an overall response rate of 33 percent.

Each family member over the age of 15 in the survey household was asked to fill out a two-day travel diary describing every trip taken over that period. Information on each trip was to include purpose, travel mode, number of people in the vehicle, trip duration, and amount of time spent at the destination.

The Location Data

The travel diary data focused on respondents' travel patterns. However, as collected on the diary, travel origins and destinations were listed as only a set of addresses, an intersection, or the name of a landmark. To make these data usable the information was geocoded. The resulting data set contains more than 24,000 addresses, intersections, and landmarks. The Census' TIGER line file for all of King County was used for address matching . Computer software successfully geocoded 65 percent of all the location with the remaining location coded by hand. Ultimately over 96 percent of the locations were successfully geocoded. The few locations that could not be coded involved a trip that was outside King County, bad information, or incomplete survey responses.

Panel Survey Data

The PSRC transportation panel survey was used as the source of comparative county-level travel characteristics. Since the PSRC data collection effort was started before the mixed-use survey project was initiated, the PSRC survey was used as the basis for the design of the mixed-use survey.

The PSRC panel survey was a major effort aimed at collecting data on the effect of transportation conditions and demographic characteristics on household travel behavior in urban areas. Only part of the PSRC survey effort (the first wave conducted in 1989) was used for this study. The data used for this study involved 663 households in King County making almost 12,000 trips (see **Murakami and Watterson** (1992) for detailed information on the survey methodology).

Identification of Trip Chains

Since the 1970s, the emphasis in many studies of transportation behavior has shifted from analysis of individual trips to that of multipurpose trips or chains. This shift is due to the recognition that understanding chained travel is crucial in understanding most individual travel behavior (**Alder and Ben-Akiva** 1979). A more accurate view of urban travel accounts for sequential, multipurpose travel and assumes accessibility changes as a person moves from one trip origin to another.

The methodology used to organize the mixed-use and PSRC data into trip chains borrowed from previous trip chaining research. Examination of the literature suggests a chaining definition on the use of home or work as an anchor point. Adler and Ben-Akiva's (1979) widely cited model of chain behavior was based on chains defined as trips to or from home. A link (which they called a sojourn) is a visit to any place remote from home. A combination of trips away from home defined a trip tour (or chains). **Southworth** (1985) divided chains into five types based on trips that started from home or work. **Strathman and Dueker's** (1994) analysis of the National Personal Transportation Survey (NPTS) used a typology based on chains that started and ended at home. Hodge, while exploring multi-purpose travel in King County (the same area as this study), considered a chain to be any set of trips that had home or work as an endpoint (1991). The trip chain was considered broken if an individual stayed at a location longer than 90 minutes.

Each of the studies listed above started and stopped (that is anchored) trip chains at a home location and sometimes at a work location. For this research, chains were also anchored at home or work. However, this study, like Hodge's, also broke chains after an individual remained at a stop longer than 90 minutes. Breaking a chain after a time threshold served as a mechanism to clearly delineate the importance of the home and work trip anchors in determining trip chains. In addition, **Richardson and Young** argued that the use of temporal constraint serves to reduce the number of unrealistically long chains and could make the process of exploring travel more tractable (1982).

DATA ANALYSIS — WEEKDAYS

Overview

In this section, travel characteristics of the inhabitants of the mixed-use neighborhoods and the PSRC survey are explored. The measure of travel most commonly used in this paper is *average daily travel mileage per person* (over age 15). This figure expresses the average per-person mileage of all trips made in one day, based on all the survey respondents fitting into the category of interest.

The analysis begins by examining the geographical areas and general travel characteristics of the survey respondents. The relationship between household income, household category, respondent's age and sex, and the average daily mileage traveled is explored. The section also looks at transit, walk and bicycle trips.

Since most urban travel involves multi-purpose trips, there is also some focus on trip chaining behavior. Given the importance of nearby destinations to the neotraditional concept, an identification of trip stops that were close to each respondent's household is also completed. Work travel is given separate consideration. This analysis looks at work chains, chain lengths, and work locations.

The data analysis then looks at the neighborhood-level travel patterns of the mixed-use respondents. This section examines the pattern of trips generated by local commercial establishments and bus stops. The trip length and travel characteristics of the mixed-use households and PSRC's King County households are directly compared. The analysis involves a number of household and income categories and analysis zones.

It should be reiterated that analysis in the weekday portion of this study compares the mixed-use data set with the PSRC data set and that both data sets were adjusted for compatibility. Since the PSRC respondents were asked only to include trips five minutes or longer, only mixed-use weekday trips of more than five minutes duration are included in comparisons.

Geographical and Household Characteristics

Geographical Variables

Because this study was driven by the geographical location of households, analysis required development of a number of distance and zonal variables. Several geographic zones were created based on when the cities or census places in the county were initially developed (**Figure 2**). The first zones were the three mixed-use neighborhoods of *Queen Anne, Wallingford and Kirkland*. The city of Seattle is divided into *north Seattle*. Since *north Seattle* encompasses the Queen Anne and Wallingford study areas, these areas were frequently compared. In the PSRC data sample 176 households were randomly sampled in north Seattle. The next zone is an *inner ring*, and about 30 cities surrounding Seattle that were developed in the 1940s, '50s and early '60s, and sampled 163 households. The *outer ring* includes both newer suburban developments and the remaining rural and unincorporated portion of King County, and sampled 248 households.

Household Characteristics

A summary of demographic characteristics of the mixed-use neighborhoods only and several King County analysis zones are shown in **Table 10.** The two mixed-use neighborhoods within Seattle are similar. The third mixed-use neighborhood, Kirkland, has a higher median age and considerably lower residential density. With the exception of income, North Seattle is much like Queen Anne and Wallingford. Inner and outer King County are also similar to each other and have larger household sizes and higher auto ownership levels than areas in Seattle.

General Travel Characteristics

Age

Both the mixed-use and PSRC surveys elicited respondents' ages. **Table 11** compares average daily travel mileage per person for each survey in eight age categories.

Across the two data sets, the King County respondents generally traveled more miles per day than did their counterparts in the mixed-use neighborhoods. Individuals from the outer area groups tended to have the highest mileage, followed by the inner areas. The Kirkland neighborhood tended to fall between the other two mixed-use neighborhoods and the King County areas. Among age groups, the youngest and oldest groups had lower mileage than did those in the more middle-age categories. The higher mileage groups in the neighborhood of Queen Anne and Wallingford tended to be older than those in the other areas.

Income

Table 12 shows the daily average mileage per person related to annual household income. The households were classified by low or high income with an income of $35,000 as the cutoff point.

For both the mixed-use neighborhoods and in King County suburban areas, individuals from the lower income households traveled less per day. Differences between lower and higher income individuals ranged from 1.9 percent (less than a mile a day) in the outer zone of King County to 23 percent (almost 8 miles day) for the Kirkland neighborhood. The PSRC survey respondents who lived in outer King County had a daily mileage that was high regardless of their income category.

The two mixed-use neighborhoods in Seattle (Queen Anne and Wallingford) also had considerably lower daily mileage per person than did the north Seattle households. The Kirkland respondents' mileage was greater than the other mixed-use neighborhoods but less than that of the inner and outer areas of King County. This perhaps reflects Kirkland's combination of mixed-use and suburban characteristics**.**

Table 10. Summary of Household Characteristics

Location	Average House-hold Size	Average Number Employees/ Household	Average Number of Vehicles/ Household	Median Age of Persons over 15	Percent Income over $35.000	Gross Density hh per Acre
Queen Anne	2.2	1.4	1.7	39	67%	7.6
Wallingford	2.1	1.3	1.6	37	56%	7.2
North Seattle	1.9	1.2	1.8	37	41%	5.4
Kirkland	2.0	1.0	1.9	47	61%	3.1
Inner	2.5	1.4	2.1	35	56%	1.2
Outer	2.7	1.4	2.2	37	55%	0.2
Urbanized King Co.	2.5	1.3	2.1	37	51%	2.0

Table 11. Average Daily Mileage Per Person by Age Group (Weekdays only)

	15-17	18-24	25-34	35-44	45-54	55-64	65-98	All Age	*Total. (n)*
Queen Anne	*19.0*	**21.2**	**18.0**	**17.7**	**22.4**	**14.3**	**14.5**	**18.2**	***670***
Wallingford	*9.5*	**13.6**	**18.1**	**16.0**	**18.8**	**19.8**	**16.9**	**16.9**	***594***
North Seattle	13.3	**20.0**	**24.5**	**24.2**	**23.4**	**21.6**	**16.6**	**22.4**	***581***
Kirkland	*12.7*	**32.6**	**31.7**	**29.8**	**26.4**	**27.2**	**21.9**	**27.1**	***589***
Inner	18.4	**31.0**	**33.3**	**35.2**	**29.5**	**28.8**	**22.0**	**30.3**	***659***
Outer	**26.0**	**43.4**	**40.3**	**42.4**	**37.0**	**34.6**	**36.9**	**38.5**	***924***

n = number of person days, italic = n less than 25

Table 12. Average Daily Mileage Per Person by Income (weekdays)

	Household Income Less Than $35,000 a Year	*(n)*	Household Income More Than $35,000 a Year	*(n)*	% Diff.
Queen Anne	14.5	*181*	19.7	*475*	26.2%
Wallingford	16.1	*231*	17.2	*353*	6.4%
North Seattle	20.3	*290*	24.3	*263*	16.5%
Kirkland	22.0	*184*	29.7	*386*	25.9%
Inner King Co.	27.6	*240*	32.2	*397*	14.3%
Outer King Co.	36.7	*346*	37.4	*549*	1.9%

n = number of daily person trips

Table 13. Average Daily Travel per Household Category (Weekdays)

	child (ren) under 6	child (ren) 6 - 17	one adult < 35	one adult 35 - 64	one adult 65+	two adults < 35	two adults 35 - 64	two adults 65+	Total (n)
Queen Anne	**19.9**	**20.0**	**6.5**	**10.7**	**19.5**	**19.6**	**16.9**	**18.2**	**671**
Wallingford	**16.9**	**17.9**	**21.1**	**16.4**	*13.9*	**15.5**	**17.5**	**17.1**	**595**
North Seattle	**29.0**	**21.7**	**19.2**	**19.9**	*14.4*	**23.0**	**22.2**	**17.1**	**636**
Kirkland	**28.2**	**29.3**	*31.2*	**23.4**	**24.2**	**32.6**	**30.4**	**21.0**	**591**
Inner King	**32.4**	**32.5**	*46.3*	**28.6**	**21.1**	**31.7**	**30.0**	**22.2**	**712**
Outer king	**45.2**	**37.1**	*36.7*	**33.4**	**42.5**	**36.6**	**37.9**	**34.0**	**998**

n = number of person days, italics = n less than 25

Household Category

A detailed analysis of mileage was completed by examining travel as related to household category. The use of household categories attempted to remove any effect that household size and type may have on daily travel patterns (**Table 13**).

Several patterns are visible in **Table 13**. For both data sets, households with young children showed higher rates of daily travel. In the King County data, households with older children also traveled a larger number of miles per day. In the mixed-use neighborhoods, individuals from households with two middle-aged adults traveled as many miles per day as did individuals from households with small children. In both data sets, the lowest mileage was found in households with individuals 65 years or older. Across the data sets, King County respondents traveled more per day than did those from the mixed-use neighborhoods.

Sex

Table 14 shows the average daily trip mileage by sex for both automobile and bus modes. The mileages for the two modes is the averaged total mileage traveled per day by a survey respondent on either transit or automobile. Some of the transit information should be interpreted with caution because of small sample sizes.

As seen in **Table 14**, men typically traveled more miles per day by automobile than did women. Among the various areas, Queen Anne and Kirkland saw the greatest difference in automobile between men and women. For transit mileage, the Queen Anne and Wallingford neighborhood showed minimal differences between the sexes. The North Seattle and Kirkland areas, on the other hand, had notably higher transit mileage.

Transit Use

Table 15 shows the relationship between transit and non-transit users in terms of daily mileage using several modes. A survey respondent is considered a transit user if they used transit for any trip during a day.

Table 15 shows that in Queen Anne, Wallingford and North Seattle transit riders traveled less miles per day than non-transit users. In the other areas the difference between transit and non-transit user was minimal. One interesting finding is the that non-transit users in the inner suburbs of King County traveled 8 percent less per day than transit users. Since the data is for weekdays, one possible reason for this situation is a long transit commute to the Seattle CBD.

Table 14. Average Daily Mileage Per Person by Mode and Sex (Weekdays)

	Automobile					Bus				
	Male	***(n)***	**Female**	***(n)***	**% diff**	**Male**	***(n)***	**Female**	***(n)***	**% diff**
Queen Anne	**20.5**	*297*	**16.9**	*279*	19.7%	**6.4**	*48*	**6.5**	*80*	-1.6%
Wallingford	**18.3**	*217*	**16.9**	*293*	7.6%	**6.6**	*58*	**6.6**	*69*	0%
North Seattle	**24.2**	*250*	**24.8**	*69*	-2.4%	**11.2**	*43*	**8.8**	*63*	21.4%
Kirkland	**28.8**	*256*	**24.2**	*308*	16.0%	**23.4**	*14*	**14.0**	*33*	40.2%
Inner King	**31.0**	*299*	**27.6**	*352*	11.0%	**16.1**	*24*	**17.7**	*23*	-9.9%
Outer King	**38.9**	*444*	**35.4**	*455*	9.0%	**22.2**	*23*	**25.0**	*30*	-12.6%

N = number of person days

Table 15. Transit and Non-Transit Users Average Daily Mileage (Weekdays)

	Non-transit User	**(n)**	**Transit User**	**(n)**	**Difference**
Queen Anne	**19.6**	514	**13.3**	127	-47.4%
Wallingford	**18.0**	423	**14.0**	126	-28.6%
North Seattle	**23.1**	490	**17.1**	106	-35.1
Kirkland	**27.3**	465	**27.8**	45	1.2%
Inner	**29.7**	618	**32.3**	47	8.0%
Outer	**37.8**	874	**37.2**	53	-1.6%

n = number of person days

Bicycle Use

In the mixed-use neighborhoods 94 weekday trips (0.9 percent) were by bicycle, while in King County 40 trips were by bicycle (0.3 percent). Because these numbers were so small a further breakdown of the bicycle trips was not completed.

Pedestrian Trips

In the mixed-use neighborhoods 7,474 trips (11.3 percent of all trips) were by pedestrians while King County had 332 trips by pedestrians (3.6 percent of all trips). It must be recognized that these figures may underestimate the number of daily walk trips since they include only trips greater than five minutes in duration. If short trips are included the number of walk trips increases. For example, for the mixed-use data, including all trips both above and below five minutes increased the number of walk trips from 11.3 percent to 15.9 percent. A distribution of walk trips by geographic area is shown in **Table 17**.

Table 17 clearly shows that the mixed-use neighborhoods of Queen Anne and Wallingford had the highest level of walking with around 18 percent of all trips on foot. North Seattle and Kirkland had fewer walking trips with 7 to 9 percent of all trip on foot. In the suburbs of King County less than 3 percent of all trips were by foot.

The distribution of weekday pedestrian trips by trip purpose is shown in **Table 18.**

Table 18 shows that the most common purpose for walk trips is personal. This is reasonable since many personal trips include walking and running for exercise as well as simply recreational walking. Not including trips that return to the home, the most common purpose for walk trips, with the exception of Wallingford, was for work. For Wallingford, shopping saw more pedestrian trips than did work.

Trip Chains

Each trip in the mixed-use and PSRC data set was assigned a chain and *link* variable. The first trip of the day for any respondent was always *chain* 1, *link* 1. If the next trip for that person started after a stay of less than 90 minutes and did not start from home that trip would be *chain* 1, *link* 2. Otherwise the next trip would be *chain* 2, *link* 1. This process continued until the next respondent or next day occurred in the data set. During this process, trips of all duration were included; removing trips of under five minutes, as occurred in other parts of this analysis, could have influenced the continuity of some of the chains. This probably had minimal impact on the analysis of chains since the PSRC respondents tended to include all trips, including those of five minutes or less. The percentage of chains by the number of stops is shown in **Table 19**.

Table 17. Walk Trips as a Percent of All Trips (Weekdays)

	Percent of Walk Trips	*n*
Queen Anne	18.1%	*610*
Wallingford	17.7%	*529*
North Seattle	8.8%	*246*
Kirkland	7.8%	*227*
Inner	2.8%	*90*
Outer	2.0%	*84*

n= number of trips(links)

Table 18. Walk Trips by Purpose (Weekdays)

	work	shop	school	personal	appoint-ment	home	*N*
Queen Anne	21.5%	13.9%	2.1%	34.1%	1.0%	27.4%	*610*
Wallingford	13.6%	17.6%	4.9%	31.6%	1.5%	30.8%	*529*
North Seattle	1.7.5%	10.2%	6.9%	35.0%	3.7%	26.8%	*246*
Kirkland	17.2%	12.3%	0.9%	42.3%	0.4%	26.9%	*227*
Inner	23.3%	12.2%	1.2%	40.5%	3.6%	21.4%	*90*
Outer	22.6%	10.7%	1.2%	40.5%	3.6%	21.4%	*84*

n= number of trips (links)

The three mixed-use neighborhoods showed similar chaining behavior. About 60 percent of all chains contained a single trip. These were mainly trips connecting home and work, or trips wherein travelers arrived at a stop and spent more than 90 minutes there. About a quarter of the chins were two-link trips. This included common trips, such as dropping a child off at day-care on the way to work, as well as going from home to do some quick grocery shopping and then returning. This indicates that a significant number of the trips taken by the mixed-use respondents involved multi-purpose travel.

The data for north Seattle and the inner and outer suburban area of King County indicated that about 70 percent of all chains were single-purpose trips that traveled directly from home or work locations without any intervening stops. This suggests that these residents have a lower rate of multi-purpose trips than do those living in the mixed-use neighborhoods.

The distribution of stops found in **Table 19** can be examined in more detail by looking at the average number of links (trips) per household per day. **Table 20** shows the

average number of links (trips) per household, while **Table 21** shows the average number of chains (under the definition used here, a single trip with an anchor at home or work is a chain).

As seen in the **Table 20**, the average number of links within each household type was similar for all locations. Across household types, those with children had the greatest number of stops per day, and households with one adult had the fewest.

Tables 20 and 21 suggest that respondents from both the mixed-use and King County had similar travel patterns in terms of the number of stops and the number of chained trips made per day. This is reasonable considering that travel demands on individuals in any type of area should also be similar. Individuals still need to travel to shop for groceries or buy clothes—regardless of where they live.

The average number of trip links per chain can be derived by combining Tables 20 and 21; the ratio is shown in **Table 22**.

Table 22 shows that the majority of all chains have one or two links or stops. Seniors have consistently more links per chain.

The nature of the survey respondents' chaining behavior can also be explored by analyzing the length of the trip chains as classified by the beginning or the ending link. For **Table 23**, the data from the three mixed-use neighborhoods are combined.

As seen in **Table 23**, for both the King County and mixed-use data, chains initiated or finishing at home are longer than those started elsewhere. Trips ending at work in the King County data were about as long as trips ending at home. However, in the mixed-use data, trips ending at work were notably shorter than trips ending at home, which suggests that mixed-use respondents made more stops coming from work than they did traveling to work.

Further investigation of chain length can be completed by examining the starting and ending purpose of each chain as shown in **Table 24**.

Table 19. Distribution of Number of Links (%) in a Trip Chain (Weekdays)

	1	2	3	4	5	6	7	8	9+
Queen Anne	61.1	26.0	7.8	2.9	1.2	0.6	0.3	0.1	0.2
Wallingford	61.1	26.0	7.9	2.9	1.1	0.5	0.3	0.1	0.1
North Seattle	69.3	20.2	6.2	2.5	1.0	0.5	0.2	0.1	--
Kirkland	58.1	26.4	9.1	3.6	1.6	0.6	0.3	0.2	--
Inner King	69.5	18.8	6.6	2.9	1.4	0.6	0.2	--	--
Outer King	68.2	18.8	7.3	2.9	1.2	0.6	0.4	0.2	0.4
All King County	72.2	17.7	5.6	2.3	0.9	0.4	0.2	0.1	0.1

Table 20. Average Daily Trip Links (Trips) per Household (Weekdays)

	Household Type			
	With child(ren)	**1 Adult**	**2+ Adults**	**Senior**
Queen Anne	12.9	5.2	10.8	6.9
Wallingford	11.5	5.3	10.4	6.9
North Seattle	10.7	4.7	10.6	7.2
Kirkland	11.4	5.2	11.6	7.0
Inner	12.0	4.7	9.6	6.8
Outer	11.3	4.1	9.2	7.7

Table 21. Average Daily Trip Chains per Household (Weekdays)

	Household Type			
	With Child(ren)	**1 Adult**	**2+ Adults**	**Senior**
Queen Anne	7.8	3.5	7.1	3.5
Wallingford	6.7	3.4	6.6	3.7
North Seattle	7.6	3.3	7.5	4.5
Kirkland	6.6	3.5	7.1	3.6
Inner	8.2	3.5	7.1	4.5
Outer	7.8	3.3	6.5	4.2

Table 22. Average Daily Trip Links per Chains per Household (Weekdays)

	Household Type			
	With Child(ren)	**1 Adult**	**2+ Adults**	**Senior**
Queen Anne	1.66	1.47	1.52	1.96
Wallingford	1.72	1.57	1.57	1.87
North Seattle	1.41	1.42	1.41	1.61
Kirkland	1.72	1.49	1.64	2.09
Inner	1.47	1.37	1.36	1.52
Outer	1.45	1.24	1.43	1.82

Table 23. Average Chain Length in Miles by Initial or Terminating Purpose (Weekdays)

	Beginning				Ending			
	Mixed	*(n)*	**King**	*(n)*	**Mixed**	*(n)*	**King**	*(n)*
Home	7.8	*5309*	10.4	*3658*	7.5	*5292*	9.9	*3593*
Work	6.3	*1810*	10.2	*1828*	5.1	*1847*	9.4	*1850*
Other	5.5	*1791*	7.0	*2250*	5.3	*1771*	8.5	*2291*

(n) = number of person chains

Table 24. Average Chain Length by Initial and Terminating Purpose

	Home				Work				Other			
	Mixed	*(n)*	**King**	*(n)*	**Mixed**	*(n)*	**King**	*(n)*	**Mixed**	*(n)*	**King**	*(n)*
Home	8.3	*2795*	13.0	*873*	7.1	*1289*	11.4	*1194*	6.1	*1192*	6.9	*1509*
Work	5.9	*1121*	10.8	*1192*	5.3	*176*	12.2	*50*	3.4	*443*	6.1	*543*
Other	5.5	*1320*	8.7	*1525*	3.4	*303*	7.4	*573*	7.1	*148*	10.3	*193*

(n) = number of person chains

For the mixed-use respondents, the longest chains are those that (1) begin and end at home; (2) begin at home and end at work; and (3) begin and end at other locations. The shortest chains are those that (1) begin at work and end at another purpose; or (2) begin at another purpose and end at work. This situation indicated that non-discretionary, work-based trips tended to be longer than more flexible, discretionary trips for other purposes (e.g., shopping, personal reasons) The longest chains were those that both started and ended at home. This category includes the greatest number of trips, and it probably includes many shopping trips from home wherein the respondent stayed less than one hour at the trip destination. Stops of less than 90 minutes would not create a new chain under this project's definition.

As seen in both **Tables 23 and 24,** the chains completed by the King County inhabitants were generally longer than those of the mixed-use inhabitants, but they followed the same patterns between purposes. However, one difference is that discretionary trips by King County inhabitants from work to other destinations were relatively longer. This suggests that the King County inhabitants may be more likely to complete errands as they travel from work or that in the suburbs you need to travel farther.

Table 25. Percent of Trip Stops By Distance from Households (Weekdays)

	Distance of Stops from Household Location		
	1.0 Miles	**1.5 Miles**	**2.0 Mile**
Mixed Use	17.4%	25.4%	38.7%
King County	4.5%	11.6%	18.2%

Trip Stops

Given the neotraditional movement's emphasis on trips to locations near home, one factor of interest is how many trip destinations are within a short distance from home. **Table 25** addresses trip ends that are less than two roadway miles from each respondent's household.

This table clearly shows that the respondents in the mixed-use neighborhoods made almost twice as many trips to stops within 2 miles of home than did the King County respondents. The difference between the data sets is especially evident for trips less than one mile from home.

Work Travel

A number of studies have indicated that understanding urban daily travel behavior requires consideration of not only an individual's household location, but his or her workplace location as well. Hanson, for example, using travel diary data from a Swedish city, concluded that many households' daily trips were tied to the journey to and from the work place (1980). Hodge, using travel diary data collected in King County, concluded that, "The journey to work remains a critical element of urban trip making, both as organizer of discretionary travel and household activities" (1991).

The following tables highlight the importance of the work trip in daily travel patterns and their role as part of multi-purpose trips. **Table 26** shows the percentage of *links* (trips) that involve a work stop.

Table 26. Percent of all trip links involving a work stop (Weekdays)

	All Day	AM[1]	PM[2]
Queen Anne	33.9%	53.4%	32.8%
Wallingford	30.7%	57.5%	36.6%
Kirkland	29.1%	55.7%	30.3%
King County	31.6%	50.8%	35.5%

[1] Any trip link that starts between 6 and 9 A.M. [2] Any link that starts between 3 and 6 P.M.

During the morning commute, more than one half of all trip links involved a work stop while about a third of all the evening commute trip links involved a work stop. The King County respondents' distribution of links per day is not notably different from that of the mixed-use respondents.

Table 27 shows the percentage of *chains* that involve at least one work stop. If trip *chains*, involving a work stop are examined, as in **Table 24** above, the predominance of the work trip is more apparent. Between 40 and 50 percent of all daily trip chains include a work stop. During both the morning and evening commute, this percentage increases to over 50 percent.

The contribution of the work trip to daily travel can also be explored by looking at average mileage for both work and non-work chains. **Table 28** shows length for work chains, and **Table 29** shows length for non-work chains. As seen in the table, except for the senior households category (which tends to include retired individuals with few work trips, and small survey sample sizes), King County work chains were slightly less than twice the length of the mixed-use chains.

Table 27. Percentage of all trip Chains involving a work stop (Weekdays)

	All Day	AM[1]	PM[2]
Queen Anne	48.4%	56.2%	57.6%
Wallingford	43.6%	59.3%	52.9%
Kirkland	41.9%	57.1%	50.9%
King County	44.8%	55.0%	51.9%

[1] Any trip chain that starts between 6 and 9 A.M. [2] Any trip chain that starts between 3 and 6 P.M.

Table 28. Average Daily Trip Mileage Per *Work* Chain

Household Type	Mixed		King County	
	Mileage	*(n)*	Mileage	*(n)*
With Children	4.9	*481*	9.2	*703*
1 Adult	4.8	*212*	7.1	*226*
2+ Adults	4.9	*706*	9.1	*912*
Senior	5.1	*61*	5.1	*45*

(n) = number of daily person chains

Table 29. Average Daily Trip Mileage Per *Non-work* Chain

Household Type	Mixed		King County	
	Mileage	*(n)*	Mileage	*(n)*
With Children	6.0	*1182*	10.1	*1512*
1 Adult	6.4	*516*	8.5	*279*
2+ Adults	5.8	*1303*	10.1	*1412*
Senior	7.4	*403*	9.5	*470*

(n) = number of daily person chains

As shown in **Table 29**, the mixed-use residents' non-work chains had about 40 percent less mileage than those of King County. A comparison of **Tables 28 and 29** reveals that work chains typically had slightly lower mileage than non-work chains.

Regional Work Trips

One concern when comparing the mixed-use and King County data was confounding effects due to differential accessibility to Seattle's Central Business District (CBD). The CBD is a major employment center for King County, as such it can be expected to attract a large number of work trips. Both Queen Anne and Wallingford are close to the CBD; Queen Anne is about two miles and Wallingford four miles away. This proximity raised concerns that any average trip length for these two neighborhoods would be shorter than other locations simply because work trips to the CBD would reduce the average trip length. These shorter work trips potentially could obscure some of the transportation effects related to mixed use.

As a means of investigating the CBD's capture of work trips, the location of each respondent's workplace was identified for both the mixed-use and King County data. **Table 30** shows the percentage of work trips that remained in the same areas as the household location, and those that traveled to the Seattle CBD and to other zones. It is apparent from **Table 30** that the Seattle CBD is indeed a significant generator of work travel for Queen Anne and Wallingford. The

CBD also attracts the same level of work trips from the north Seattle zone. This finding is particularly relevant to this research because the north Seattle study area includes the Queen Anne and Wallingford neighborhoods. Because of the equal percentage of work trips traveling to the CBD from each of these areas, we conclude that differences in average trip lengths between these areas are probably not unduly influenced by travel to the CBD.

Table 30 indicates that Seattle's CBD is a major location for work sites for King County's inner and outer zones. This is reasonable given the large size of these areas. However, as expected, most of the work sites for these two zones remained internal to the areas. The majority of the work locations for the Kirkland residents remain within the inner King zone.

Household Location and Commercial Establishments

Since each mixed-use household address was geocoded to a latitude and longitude, it was possible to determine each household's distance from commercial streets. This information made it possible to relate travel behavior of individuals to the accessibility to local goods and services. Accessibility was measured by the straight line distance between each household and the nearest commercial street. Commercial streets were selected based on concentrations of establishments providing goods and services used on a routine basis, including grocery stores, convenience stores, restaurants, dry cleaners, and drug stores.

Table 30. Work Trip Destinations (%)

Location	Within Location	To CBD	To North Seattle	To Inner King	To Outer King
Queen Anne	10.5	30.9	41.6	11.5	4.5
Wallingford	10.4	24.8	46.4	11.4	5.2
Kirkland	14.3	11.6	6.4	52.9	16.5
North Seattle	42.0	31.0	42.0	8.4	6.1
Inner King	52.7	12.6	9.2	52.7	10.5
Outer King	44.5	6.8	4.1	31.0	44.5

One tenet of the mixed-use movement is that nearby commercial establishments reduce the need to drive. One test of this idea is to compare levels of walking for mixed-use residents living at different distances from commercial areas. **Figure 3** shows the percentage of shopping trips that were completed on foot by households at five different distances from the commercial streets. This analysis includes only shopping trips that have at least one trip end within a census tract that includes the mixed-use neighborhoods. As expected, the figure indicates that the farther mixed-use inhabitants live from a commercial street, the less likely their shopping trips will be on foot (and more likely in an automobile). This trend is particularly noticeable for the Queen Anne and Wallingford data. Over 65 percent of the residents from Queen Anne and 50 percent of those from Wallingford, who also lived within 0.1 mile of a commercial street, walked to shop. In contrast, fewer than 25 percent of those respondents who lived more than 0.2 mile from commercial establishments walked. (These trips could be going anywhere—not just to the local commercial street).

The Kirkland data showed a less obvious trend because of low numbers of walk trips and small survey sample sizes. Kirkland also had a more dispersed pattern of commercial activity than did the other two mixed-use neighborhoods, rendering any patterns less obvious.

The same analytical process was applied to recreation and personal trip purposes **(Figure 4).** Personal and recreational purposes include eating and drinking, pleasure trips, and family/personal business. As seen in the figure, the overall relationship between walking trips and distance is also noticeable for recreation/personal trips. Since many of these purposes involve commercial establishments, it is not surprising that this level of walking shows a similar trend to shopping purposes.

Travel Mileage

Travel distance information from the PSRC's King County data was compared to data from the mixed-use neighborhoods. During this stage of analysis, an effort was made to control for sample bias, which was achieved by comparing travel mileage between similar household types and incomes. Because of small sample sizes, various categories were aggregated, and different analysis zones were used.

The average daily mileage by mode for Queen Anne and Wallingford combined (the Seattle mixed-use neighborhoods), Kirkland; north Seattle; and the inner and outer areas (the King County suburban areas) is shown in **Figure 5.** For all modes the following progression was observed: the Seattle mixed-use neighborhoods had the lowest mileage per day, north Seattle the next lowest, followed by Kirkland. The King County suburban areas had the highest daily mileage. Across modes, automobile use had the highest mileage. For transit the difference in average mileage for the two mixed-use neighborhoods and the King County suburban areas was 14 miles per day. For automobile use, this difference was almost 16 miles a day.

Figure 6 compares average daily travel mileage per trip by purpose. Again, there was a notable progression of trip mileage: trip length increased from Seattle mixed-use to north Seattle to Kirkland to suburban King County. In most cases, the Queen Anne + Wallingford mixed-use respondents traveled half the distance per trip than did those living in suburban King County. Across purposes, work trips had the highest average mileage, and shopping trips had the lowest trip mileage.

This average daily travel information can be subdivided by income. Since it was shown previously that daily mileage varies with household income, daily average mileage was separated into higher and lower income categories. **Figure 7** shows the travel mileage for individuals from households with high and low incomes. Again, the Seattle area mixed-use neighborhoods showed the lowest mileage, and the King County suburban areas showed the highest. Those from households with lower incomes consistently traveled fewer miles per day than those from higher income households.

The travel mileage data can be broken down in more detail by location. **Figure 8** shows some of the same data as above, but disaggregated into the three mixed-use neighborhoods and the three King County zones. As with the previous figures, the Seattle mixed-use neighborhoods had the lowest daily person mileage, and the suburban King County areas had the highest. The Kirkland mixed-use neighborhood respondents had higher mileage than other mixed-use neighborhoods and north Seattle, but lower mileage than the King county suburban zones. This finding supports the idea that Kirkland is a transitional neighborhood between mixed land use and traditional suburban land use.

The results depicted in **Figure 9** support some of the earlier findings in that individuals from households with children traveled the most and that those from households with seniors traveled the least. Those who lived in the Seattle area mixed-use neighborhoods consistently traveled fewer miles than the respondents from the King County data sets. In every case, the two Seattle mixed-use neighborhoods also had a lower average mileage than similar households in north Seattle.

Table 31 summarizes average daily travel mileage for several locations, household types, and two income levels. With the exception of categories with a small sample size, respondents from the Seattle mixed-use neighborhoods (Queen Anne and Wallingford together) had the lowest mileage for each household type and income category. North Seattle was the next lowest, followed by the inner King County cities, and then outer King County. Except for the senior households category (characterized by a small sample size), the higher income households had higher average daily mileage than their lower income counterparts.

Travel Time

As noted in the literature search, Gordon and Richardson (1994) pointed out that while work trip distances have increased, so have travel speeds, confirming a finding supported by this data analysis. Hupkes (1982) summarized trip rates and travel times for the

Table 31. Average Daily Travel Mileage by Household type and Annual Household Income (Weekdays)

	< $35,000		> $35,000	
With Child(ren)	**miles**	***(n)***	**miles**	***(n)***
Queen Anne + Wallingford	13.13	*96*	15.26	*663*
North Seattle	25.88	*44*	26.93	*96*
Inner	30.17	*79*	34.20	*189*
Outer	36.73	*133*	41.45	*242*
One Adult				
Queen Anne + Wallingford	16.53	*183*	17.56	*100*
North Seattle	20.53	*61*	18.15	*12*
Inner	30.85	*38*	36.45	*16*
Outer	37.23	*39*	28.00	*10*
Two Adults				
Queen Anne + Wallingford	11.75	*264*	15.48	*669*
North Seattle	20.58	*117*	24.49	*140*
Inner	27.34	*66*	31.88	*166*
Outer	37.85	*117*	36.64	*279*
Senior				
Queen Anne + Wallingford	12.04	*153*	16.17	*98*
North Seattle	17.27	*60*	11.69	*10*
Inner	23.79	*56*	21.55	*21*
Outer	38.04	*50*	28.63	*19*

(n) = number of daily person trips

U. S. and European countries and reported the average daily travel per person to range from 65 minutes to 84 minutes. The U. S. travel time in Hupkes' paper was 83 minutes for 1965/66 and was an average of 44 urban areas. Purvis (1994) calculated an average for the San Francisco Bay Area of 82.5 minutes per person in 1990. These observations seem to be confirmed the data analysis reported in **Tables 32**, **Table 33** and **Table 34.** These tables also show that substantial differences in daily travel distances among areas analyzed were not maintained when travel time was taken into account.

Table 32 indicates that for all ages all areas were clearly similar in the number of minutes spent traveling per day. Of all the age groups, the 18- to 24-year-olds in Queen Anne, Wallingford and outer King County tended to spend the most time traveling. For the remaining age groups, those in the middle ages categories had longer travel times. The Seattle area average of about 90 minutes compares fairly well with the Bay Area when you consider that the Seattle survey collected

no travel data from those younger than age 16 and the Bay Area started with age 5. NPTS (1995) reports shorter and fewer trips for these younger people and leaving them out raises the average travel time for those remaining.

Table 32. Average Daily Minutes of Travel Per Person by Age Group (weekdays)

	15-17	18-24	25-34	35-44	45-54	55-64	65-98	All Ages	Total (n)
Queen Anne	*89*	**111**	**90**	**92**	**99**	**81**	**81**	**91.8**	**670**
Wallingford	*84*	**96**	**92**	**93**	**90**	*88*	**83**	**91.1**	**594**
N. Seattle	*89*	**85**	**93**	**88**	**89**	**78**	**75**	**86.2**	**596**
Kirkland	*99*	**81**	**86**	**98**	**100**	**96**	**80**	**90.1**	**589**
Inner King	*61*	**96**	**88**	**99**	**88**	**89**	**82**	**89.6**	**665**
Outer King	**57**	**109**	**95**	**94**	**92**	**96**	**100**	**93.8**	**925**

n = number of person days, italics = n less than 25

Table 33. Average Daily Minutes of Travel per Household Category (weekdays)

	child < 6	child 6 - 17	one adult < 35	one adult 35 -64	one adult 65+	two adults < 35	two adults 35 -64	two adults 65+	Total (n)
Queen Anne	**88**	**97**	**75**	**90**	**66**	**103**	**90**	**91**	**671**
Wallingford	**81**	**85**	**100**	**100**	*87*	**93**	**102**	**79**	**595**
North Seattle	**88**	**81**	**89**	**86**	*54*	**93**	**88**	**77**	**596**
Kirkland	**83**	**88**	*76*	**91**	**83**	**90**	**105**	**81**	**591**
Inner	102	**81**	*83*	**82**	**82**	***88***	**107**	**94**	**665**
Outer	**95**	**88**	*86*	**87**	**145**	**73**	**97**	**90**	**925**

n = number of person days, italics = n less than 25

Table 33 is interesting in the variability, as well as the similarity apparent among household trips in the mixed-use and King County areas. In a number of age categories, individuals from the outer suburbs had the longest time travel (one adult 65+, children under six) but for another types of household this area had among the shortest travel times (two adults < 35). The Wallingford neighborhood had the longest travel times for the several household types (one adult < 35, one adult 35 - 64) but among the shortest for households 65+. The Queen Anne neighborhood had the longest travel time for households with two adults 35-65 but the shortest for one adult 65 +.

Table 34 indicates that the great difference in travel mileage between the mixed-use neighborhoods and the King County area is not nearly as apparent as the difference in travel times. The average speed for each area shows significantly lower travel speeds for the Queen Anne and Wallingford respondents compared to other areas. Given that these areas had a higher use of the slower transit, bike and walk modes, and higher levels of congestion, this finding is reasonable.

Table 34. Average Daily Time Vs Average Daily Travel Miles (Weekdays)

	Average Daily Travel Minutes	Average Daily Travel Mileage	Average Travel Speed (MPH)
Queen Anne	92	18.2	11.9
Wallingford	91	16.9	11.1
North Seattle	86	22.4	15.6
Kirkland	90	27.1	18.1
Inner	90	30.3	20.2
Outer	93	38.5	24.8

DATA ANALYSIS — WEEKEND TRAVEL

Overview

The previous section detailed weekday travel characteristics of respondents in both the mixed-use neighborhoods and in greater Seattle. While the journey to work still dominates transportation research, travel for shopping, as well as family and personal business, is the fastest growing element of household vehicle miles traveled (**Comsis 1994**). Weekend travel primarily consists of these categories, and the potential transportation benefits for mixed-use residents who can shop nearby are intuitive.

This section looks at weekend travel from the mixed-use survey. While no comparisons could be made with the PSRC data (wherein no weekend data were collected), descriptive statistics regarding weekend travel for the three mixed-use neighborhoods are presented. General travel characteristics, variations between time of day, and Saturday versus Sunday, as well as a separate look at short walking trips, provide insight into the weekend travel patterns of mixed-use respondents.

Because only the mixed-use neighborhood data are used for this section, the analysis includes all trips made by survey respondents, including those trips under five minutes in length. Again all survey respondents are over age 15 years.

Households

There were 775 people living in almost 450 households providing weekend travel data for this study (see **Table 35**). In general, the demographics of these households are comparable with the mixed-use households described earlier; the weekend data are merely a subset of the overall data set. As before, these data do not evaluate children under 15 years of age because they did not fill out the travel diary surveys.

Table 35. Number of Households and People with Weekend Trips

	Number of Households	Number of Participants
Queen Anne	146	257
Wallingford	156	283
Kirkland	144	235

General Travel Characteristics

Basic Trip Information

A total of 5,699 weekend trips were taken by respondents in the three neighborhoods. **Table 36** depicts the trip distribution by neighborhood and day.

Trip Purpose

Distribution by trip purpose is shown in **Figure 10**. Unlike weekday travel, trips for school and work accounted for less than seven percent of all trips. Thus, they are not considered to be a factor on weekends. Trips for shopping, personal, and "home" accounted for more than 90 percent of all trips. Trip purposes by percentage were generally similar across the three neighborhoods.

Trip Mode

The predominant modes of choice in all three neighborhoods for weekend travel were either car or walking **(Figure 11).** Since less than five percent of all trips utilized a bus, bike or "other" mode, later analysis involving travel modes will include only car and walking trips.

The corresponding percentages for auto and walk travel are displayed in **Table 37**. While all three neighborhoods chose the auto predominantly as a travel mode, Queen Anne and Wallingford saw high percentages of walk trips, while Kirkland had only half the percentage walk trips of the other two neighborhoods.

Table 36. Weekend Trip Information

	Total number of trips	Number of Saturday trips	Number of Sunday trips
Queen Anne	2036	1119	917
Wallingford	1946	1062	884
Kirkland	1717	948	769

Table 37. Weekend Auto and Walk Percentages

(% of trips)	Auto	Walk
Queen Anne	76.2 %	18.9 %
Wallingford	75.5 %	18.8 %
Kirkland	89.1 %	9.1 %

Trip Length

Trip length is among the most frequently used measures of travel. The overall average trip length in miles for each of the three neighborhoods is shown in **Table 38.** Queen Anne and Wallingford had similar numbers, while Kirkland's average length was somewhat longer. Because the average lengths for the two predominant modes (walking and auto) was so different, individual averages are provided as well.

Beyond average trip length, the distribution of trip lengths in the three neighborhoods is also of interest insofar as it is distinctly different. **Figure 12, Figure 13,** and **Figure 14** are trip length histograms for each neighborhood. Queen Anne had many trips under one-half mile, with very few longer trips. Wallingford's histogram was less angled, but still indicated an emphasis on shorter trips. Kirkland however, beyond the very short trips, and saw a resurgence of trips at the 4-mile mark, and again at the 10-mile mark.

Trip Duration

Average weekend trip duration varied from 16.7 minutes for Queen Anne to 19.3 minutes for Wallingford. The Kirkland average duration was between the two at 18 minutes. As with the weekday data, the time duration of trips in these areas, due to increase speeds, show less variability than the distance in miles. Average auto trip duration is listed in **Table 39** (walking trips are addressed later). Queen Anne respondents spent the least time traveling by car for each trip. Yet as indicated in the second part of the table, Queen Anne residents spend the most amount of time traveling on a daily basis. This is consistent with the average daily travel minutes for weekday travel, and concurs with later findings that Queen Anne residents travel more frequently than those living in the other mixed use neighborhoods.

Table 38. Average Weekend Mileage Per Trip

	Ave. Trip Length	Ave. Auto. Trip Length	Ave. Walk Trip Length
Queen Anne	3.9	4.5	0.3
Wallingford	4.0	4.9	0.5
Kirkland	5.1	5.6	0.4

Table 39. Average Minutes of Travel

	Per trip (autos only)			Per day (all modes)	
	Weekend	Saturday	Sunday	Weekend	Weekday comparison
Queen Anne	16.3	16.3	16.2	94	92
Wallingford	19.5	19.4	19.7	89	91
Kirkland	17.9	17.8	17.9	90	86

Total Distances Per Day

The average total distance per person per day is shown in **Table 40**. Kirkland respondents had 20 percent longer distances than did Queen Anne and Wallingford respondents. This may correspond to the longer individual trip distances seen in **Table 38**. Yet because the average duration was longer, the general travel speeds are somewhat higher in Kirkland, as noted above. This confirms patterns seen in the weekday analysis where Kirkland had the highest travel speeds of the three mixed use neighborhoods.

The average total distance per household per day is shown in **Table 41**. Wallingford households in general traveled the least, while residents in all three neighborhoods traveled much less on Sunday than on Saturday.

Frequency

This measure is indicated by trips per person per day or by trips per household per day. **Table 42** shows that the overall frequency is not significantly different among the three neighborhoods, although Queen Anne residents traveled most often. All residents tended to stay home more often on Sunday.

Table 40. Average Daily Mileage Per Person (Weekend)

	Weekend	Saturday	Sunday
Queen Anne	21.5	24.7	18.1
Wallingford	18.3	19.5	17.0
Kirkland	24.5	27.0	21.7

Table 41. Average Daily Mileage Per Household (Weekends)

	Weekend	Saturday	Sunday
Queen Anne	36.8	42.6	30.8
Wallingford	31.3	33.5	28.9
Kirkland	37.7	42.4	31.5

Table 42. Average Weekend Trip Frequency

	number of trips per hh		number of trips per person	
	Saturday	Sunday	Saturday	Sunday
Queen Anne	10.5	8.9	6.1	5.2
Wallingford	8.9	7.3	5.0	4.2
Kirkland	8.4	7.2	5.2	4.7

Because mixed-use neighborhoods may encourage more walk trips, it is important to study frequency by mode (**Table 43)**. Auto trip frequencies were very similar, but a difference is clearly apparent in the walk trips per person per day. Kirkland saw only half the frequency of the two mixed-use neighborhoods.

Number of people in party

The average number of people in a party for each trip varied from 1.60 for Wallingford, to 1.70 for Kirkland to 1.73 for Queen Anne. The distribution shows very similar behaviors among the three neighborhoods, with more than 80 percent of all trips taking place either alone or with one other person.

Chaining Information

As people link more of their travel together, traditional travel measures such as number of trips may no longer reflect the amount of travel accurately. Calculating the number of links per chain provides a better measure of the efficiency of a resident's travel. Tabular results are shown in **Table 44,** while the distribution for links per chain is shown in **Figure 15**. For all three neighborhoods, about half of all trips had more than one link.

Table 43. Average Daily Trips Per Person by Mode (Weekend)

	Automobile Trips			Walking Trips		
	All Wknd	Sat.	Sun.	All Wknd	Sat.	Sun.
Queen Anne	4.31	4.70	3.90	1.07	1.04	1.10
Wallingford	3.48	3.79	3.17	0.86	0.91	0.82
Kirkland	4.43	4.70	4.14	0.45	0.44	0.46

Table 44. Number of Links Per Chain (Weekend)

Queen Anne	1.88
Wallingford	1.68
Kirkland	1.79

Data Comparison

Day of Week

The travel patterns of mixed-use residents were not necessarily the same as opposed to Saturday and Sunday. The top part of **Table 45** shows a summary of several travel measures for the two weekend days. In general, travel distance decreased on Sunday (except for the average distance per trip in Wallingford). Travel frequency decreased in all three neighborhoods on Sunday. Travel duration and efficiency (links per chain) remained relatively constant over the weekend.

The bottom portion of **Table 45** lists compatible travel measures for the same residents on an average weekday. Trip distance (average trip length) and duration were similar from weekdays to weekends, while the number of trips and distance per person per day appeared to increase on the weekends.

There was very little variation in trip purpose between Saturday and Sunday. As indicated in **Table 46**, respondents from all three neighborhoods did a significant amount of travel for shopping and personal purposes. Kirkland saw a 50 percent drop in work trips between Saturday and Sunday.

Table 45. Travel Measures by Day of Week

	Distance per person per day	Distance per hh per day	Distance per trip	Minutes per trip	Trips per person per day	Links per chain
Saturday						
Queen Anne	24.7	42.6	4.2	16.8	6.1	1.9
Wallingford	19.5	33.5	3.9	19.2	5.0	1.7
Kirkland	27.0	42.2	5.4	17.9	5.2	1.8
Sunday						
Queen Anne	18.1	30.8	3.5	16.5	5.2	1.9
Wallingford	17.0	28.9	4.1	19.4	4.2	1.6
Kirkland	21.7	31.5	4.7	18.1	4.7	1.8
Average Weekday						
Queen Anne	18.7	31.9	4.0	17.0	7.2	1.7
Wallingford	17.1	28.1	3.8	17.4	6.7	1.7
Kirkland	28.0	45.3	4.9	17.3	10.0	1.8

Table 46. Trip Purpose by Day of Week (% of Trips on that Day)

	Work	Shop	Personal	Home
Saturday				
Queen Anne	6.2 %	20.9 %	39.9 %	32.2 %
Wallingford	7.0 %	19.8 %	35.7 %	36.8 %
Kirkland	6.3 %	22.6 %	37.7 %	32.7 %
Sunday				
Queen Anne	5.9 %	19.7 %	38.5 %	35.7 %
Wallingford	7.1 %	17.5 %	36.1 %	38.6%
Kirkland	*3.0 %*	22.9 %	39.0 %	35.1 %

Italics = n less than 25

Table 47. Trip Mode by Day of Week (Percent of Trips on that Day)

	Auto	Walking
Saturday		
Queen Anne	77.3 %	17.1 %
Wallingford	76.0 %	18.3 %
Kirkland	89.8 %	8.4 %
Sunday		
Queen Anne	74.8 %	21.0 %
Wallingford	75.0 %	19.3 %
Kirkland	88.3 %	9.9 %

The trip mode analysis is again restricted to auto and walking insofar as those are the only modes that are factors in these neighborhoods. **Table 47** shows the variation in trip mode throughout the weekend. Walking percentages increased in all the study neighborhoods on Sunday.

Hourly Distributions

This analysis investigated when residents travel during the day. **Figure 16** shows the hourly distribution for Saturday and Sunday. Typically, people travel later on Sundays than Saturdays. This is apparent in the differing peak locations in the distribution table.

Other Weekend Research

Two studies discussed in the literature search explored weekend travel in suburban areas. **Table 48** reflects Murakami's (1996) finding of average weekend trip length of 7.9 miles for

suburban areas throughout the country. The three mixed use neighborhoods have, to varying degrees, a shorter average trip length than Murakami reported. The second column of the table shows the weekday average trip length comparison between the mixed use neighborhoods and the PSRC study areas. It is interesting to note that the mixed use neighborhood trip lengths are very similar between weekends and weekdays, and the Murakami number closely resembles the average trip length for outer ring suburbs.

The second study (Hu 1996) cataloged travel behavior by day of week for suburban areas. The author detailed multitudes of variables and travel characteristics. **Table 49** shows a few select measures that can be compared to measures in this data set and to average weekday numbers from the PSRC data. Such a comparison shows that travel frequencies are similar regardless of household location while the average trip lengths clearly increase in more suburban areas. In addition, women tend to travel more often than men. These findings concur with the ratio between mixed use trip length and suburban trip seen in Murakami's comparison above.

Table 48. Murakami - Average Trip Length Comparison

	Weekend	Weekday
Murakami (suburban)	7.9	
North Seattle	- -	4.7
Inner	- -	6.1
Outer	- -	8.0
Queen Anne	3.9	4.0
Wallingford	4.0	3.8
Kirkland	5.1	4.9

Table 49. Hu - Weekend Travel Comparison

	Freq. by household income 40k+	Freq. by gender (male/female)	Ave. trip length for shopping (miles)
Hu (suburban)	approx. 4.8	approx. 2.9 / 2.9	5.9
N. Seattle*	approx. 5.0	4.7 / 5.3	5.1
Inner*	approx. 5.1	4.7 / 5.3	8.7
Outer*	approx. 5.0	4.5 / 5.3	12.3
Queen Anne	approx. 5.8	5.6 / 5.7	3.1
Wallingford	approx. 4.7	4.6 / 4.7	3.2
Kirkland	approx. 5.1	4.9 / 5.1	3.5

* = Weekday data

Walking Trips

Much has been written about the possibility of walking trips substituting for auto trips in mixed-use neighborhoods. A number of studies reviewed in the literature search indicated that people will use their cars less in neighborhoods where goods and services are nearby.

The mixed-use data for this study are more complete than for most because the database includes short walking trips. This section takes a specific look at these weekend walking trips. There were a total of 749 pedestrian trips in the data base completed by 293 individuals. See **Table 50** for the neighborhood distributions of these trips.

Age

The average age of people who undertook walking trips is shown in **Table 51.** It does not appear different from the average age of all the study respondents.

Table 50. Weekend Walk Trip Distribution

	Number of Walking Trips	Number of Individuals With Walking Trips
Queen Anne	384	113
Wallingford	365	118
Kirkland	156	62

Table 51. Average Age of People Who Walk on Weekends

	Average Age (Years)
People Who Walk	
Queen Anne	42.5
Wallingford	37.4
Kirkland	49.3
All Participants	
Queen Anne	41.6
Wallingford	39.6
Kirkland	48.7

Household Type

An interesting finding is that people who walk appear to come from larger households on average than that of the respondents as a whole. There are more adults and children in households with walking trips (**Table 52).**

Tables 53 and **54** list the walking rates by day of week for various household types. The first set of rates includes only households with walking trips, while the second set of numbers displays the average walking rates based on all households. Individual numbers for "Households with walking trips" are not included because the number count of households is low (between 2 and 25).

Table 52. Household Characteristics of People Who Walk on Weekends

	Household Size	Number of Adults per Household	Number of Children per Household
People who Walk			
Queen Anne	2.50	1.94	.52
Wallingford	2.47	2.07	.43
Kirkland	2.02	1.81	.21
All Participants			
Queen Anne	2.16	1.69	.47
Wallingford	2.15	1.81	.34
Kirkland	2.04	1.72	.32

Two-adult households without children walk most often. Interestingly, households with children do not walk less than other types of households. There does not appear to be a large difference between Saturday and Sunday walking rates within the three neighborhoods.

Table 53. Average Daily Walking Trip Per Household by Household Type (Saturday)

	Household Type				Total (walking trips per household)
	With Child(ren)	1 Adult (no children)	2 Adults (no children)	Seniors	
Households with Walking Trips					
Queen Anne					3.67
Wallingford					3.40
Kirkland					2.67
All Households					
Queen Anne	2.23	1.46	2.28	*.55*	1.79
Wallingford	1.59	1.63	1.81	*1.17*	1.75
Kirkland	*.76*	.25	.86	*1.05*	0.71

Italics = (n) households less than 25

Table 54. Average Daily Walking Trip Per Household by Household Type (Sunday)

	Household Type				Total (walking trip per hh)
	With Child(ren)	1 Adult (no children)	2 Adults (no children)	Seniors	
Households with Walking Trips					
Queen Anne					3.94
Wallingford					3.05
Kirkland					2.81
All Households					
Queen Anne	1.80	1.59	2.20	*2.00*	1.87
Wallingford	2.00	1.27	1.49	*0.71*	1.46
Kirkland	*0.19*	*1.00*	0.73	.80	0.72

Italics = (n) households less than 25

Number of vehicles

An interesting finding (**Table 55)** is that people who walked tended to have similar or slightly more vehicles than other survey respondents.

Annual Income

Table 56 shows walking rates by annual income for the three neighborhoods. Lower income residents walk more often than those in higher income households. Queen Anne residents walk most often, while as shown earlier, Kirkland's walking rates are lower than those in the other two neighborhoods.

Table 55. Average Number of Vehicles of Those Who Walk

	Average Number of Vehicles
People Who Walk	
Queen Anne	1.96
Wallingford	1.64
Kirkland	1.65
All Participants	
Queen Anne	1.74
Wallingford	1.62
Kirkland	1.89

Table 56. Average Daily Walking Rates by Annual Income

	Annual Household Income	
	Less than $ 35,000 a year	More than $35,000 a year
Number of trips per person per day		
Queen Anne	1.43	0.89
Wallingford	0.82	0.77
Kirkland	0.51	0.43
Number of trips per household per day		
Queen Anne	1.88	1.71
Wallingford	1.24	1.53
Kirkland	0.73	0.71

Trip Length

Figure 17 illustrates the trip length histogram for walking trips. Seventy-three percent of trips were less than one-half mile, and 40 percent of the trips were less than one-quarter mile. Very few people will undertake walking trips of more than one mile.

CONCLUSION

The large body of literature reviewed for this paper generally supports the notion that mixed-use or neotraditional neighborhoods can reduce the amount of travel for most households, as measured by the number of miles traveled. The research underlying this paper generally found support for these notions, although we concur with others that the linkage is very complex. Residents of the two mixed-use neighborhoods in Seattle traveled 27 percent fewer miles than the remainder of North Seattle, 72 percent fewer than the inner suburbs and 119 percent fewer than the outer suburbs. If one of these mixed-use neighborhood were somehow relocated to the outer suburbs would it travel characteristics remain the same? It's doubtful, but indications from this research based on looking at various breakdowns of trip and household types make it clear that substantial reductions in travel distances can be accomplished with appropriate urban design.

The paper also looked at weekend travel for the mixed-use neighborhoods. This analysis showed that travel miles on Saturday were about 25 percent greater than Sunday, and Saturday travel was 12 percent greater than the average weekday. Distance per trip for weekend travel was essentially the same as weekday. Comparison of the mixed-use neighborhood weekend data to NTPS weekend travel for suburban sites showed a similar ratio of travel distances as found for comparisons of weekday travel in mixed-use sites and King County suburbs. There is some evidence that mixed land uses has the same effect on weekend trips as weekday trips.

This paper also gives credence to the few researchers who have looked at travel time rather than distance as a principal measure. The large differences among the areas reported for travel distance are not seen when considering travel time. The travel time was about 90 minutes per person regardless of where that person lived. Variation by age and family life cycle stage was also remarkably small. This "travel time budget" of about 90 minutes is an interesting finding and compares favorably to previously cited studies.

This research has several implications for travel demand modeling. First, in order to model new (old) neighborhood forms, short trips must be handled much better than in the past. The sheer number of short trips and the fact that they are substituting for longer trips that would be made in more modern suburbs dictates they be modeled more faithfully. Transportation zone boundaries swallow entire neighborhoods, making consideration of pedestrian and many bicycle trips very difficult. Second, if travel time budgets are as uniform as found in this work and shown in others, perhaps they could be used more in the calibration and validation process to assure that models operate within time constraints by various parameters. Third, the travel time budget issues and close ties between land use and short trips reinforce the notion that feedback loops are an increasingly important part of the travel forecasting process.

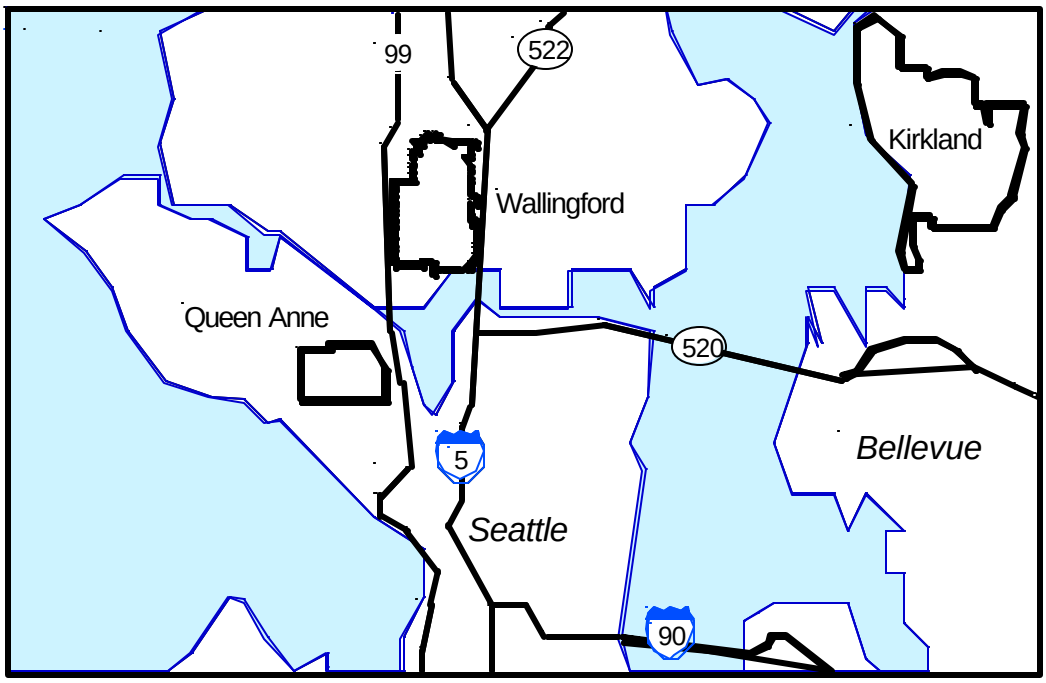


Figure 1. Study Area Vicinity Map

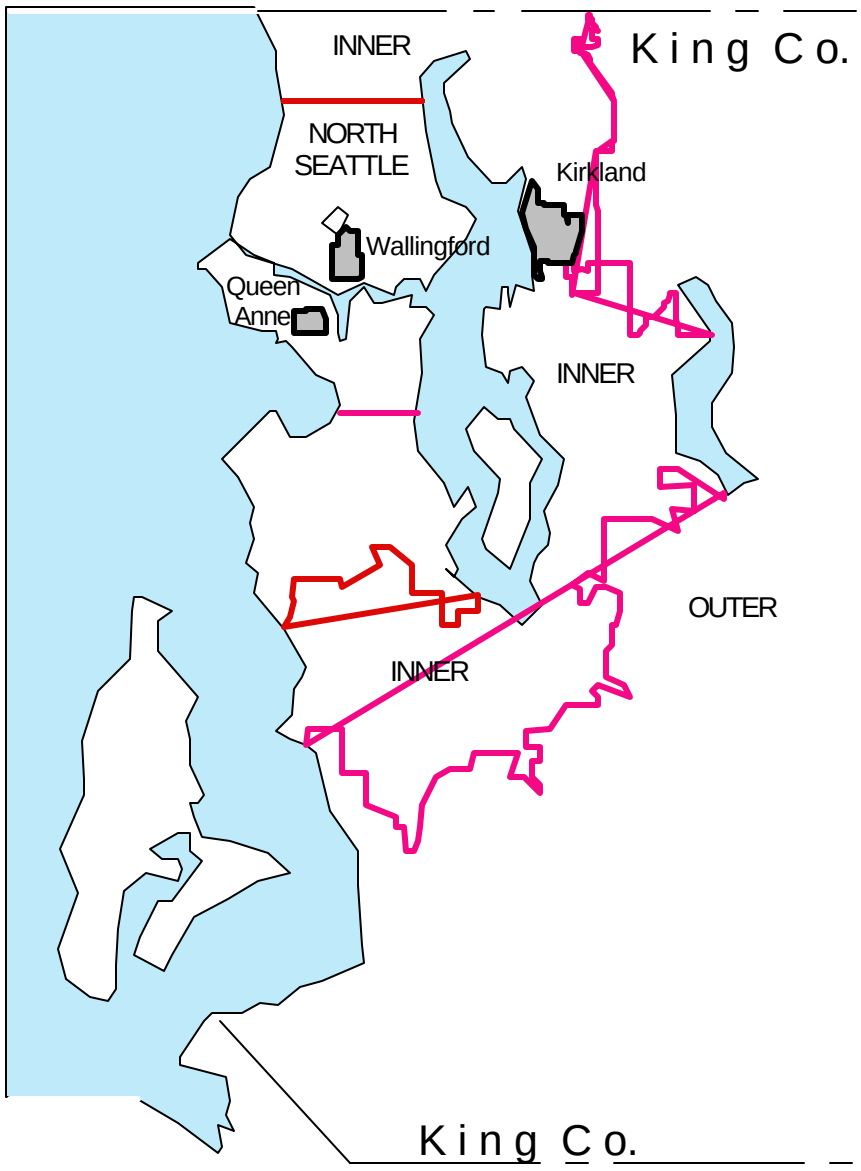


Figure 2. Analysis Zones

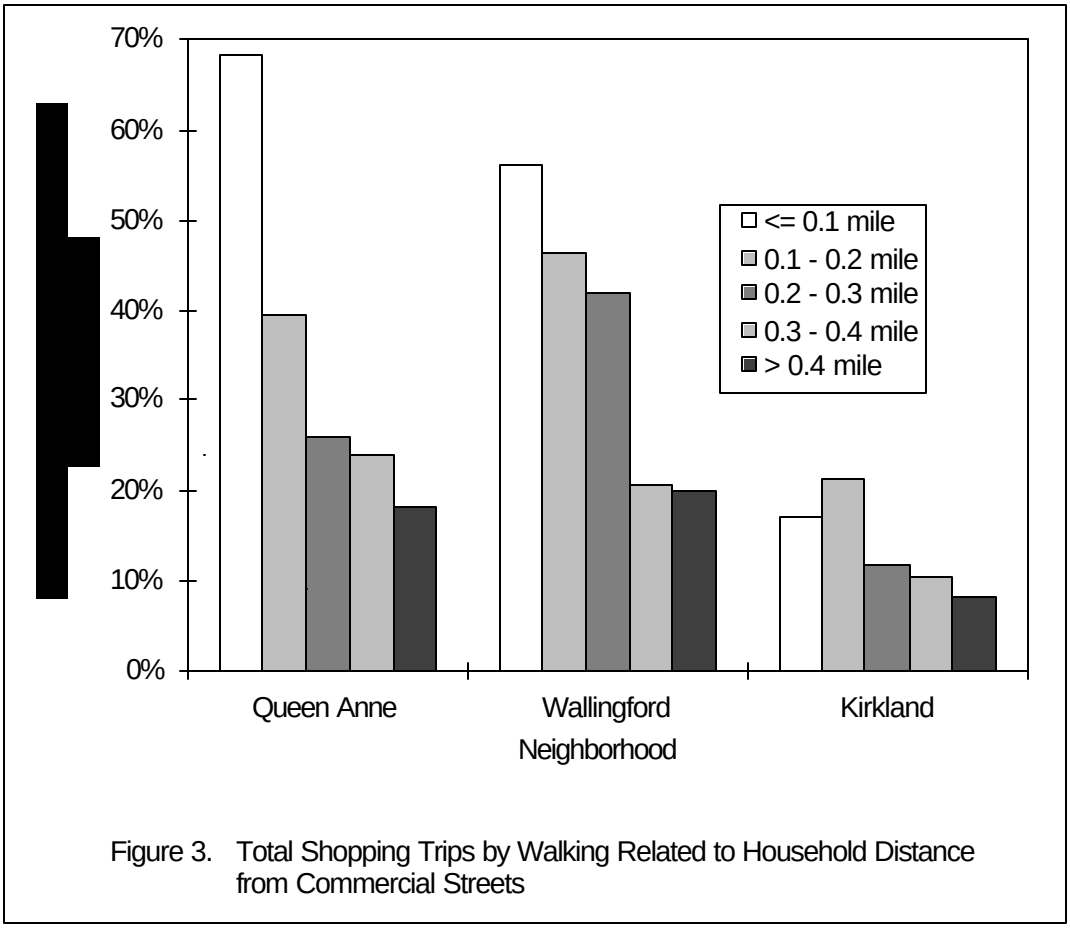


Figure 3. Total Shopping Trips by Walking Related to Household Distance from Commercial Streets

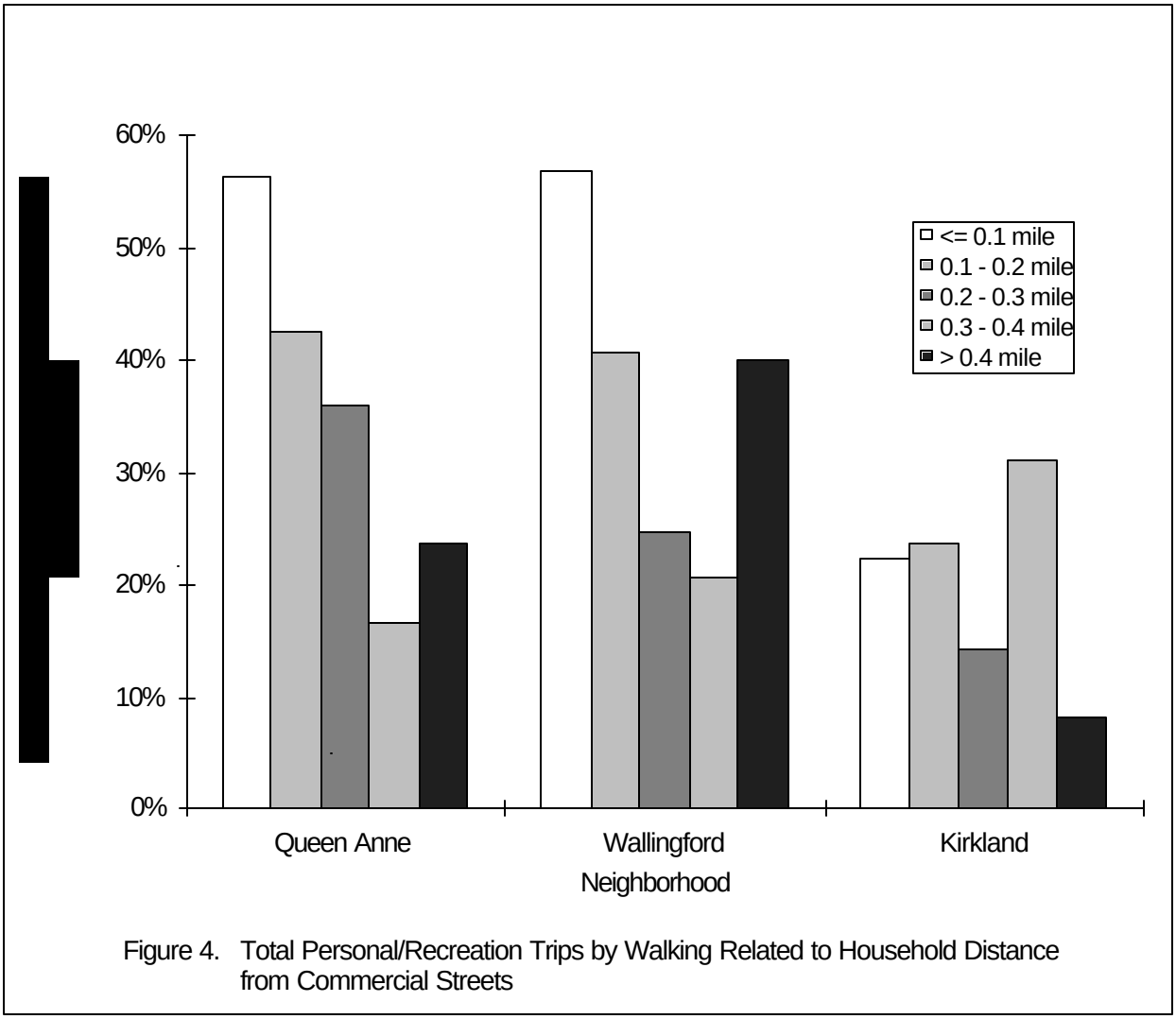
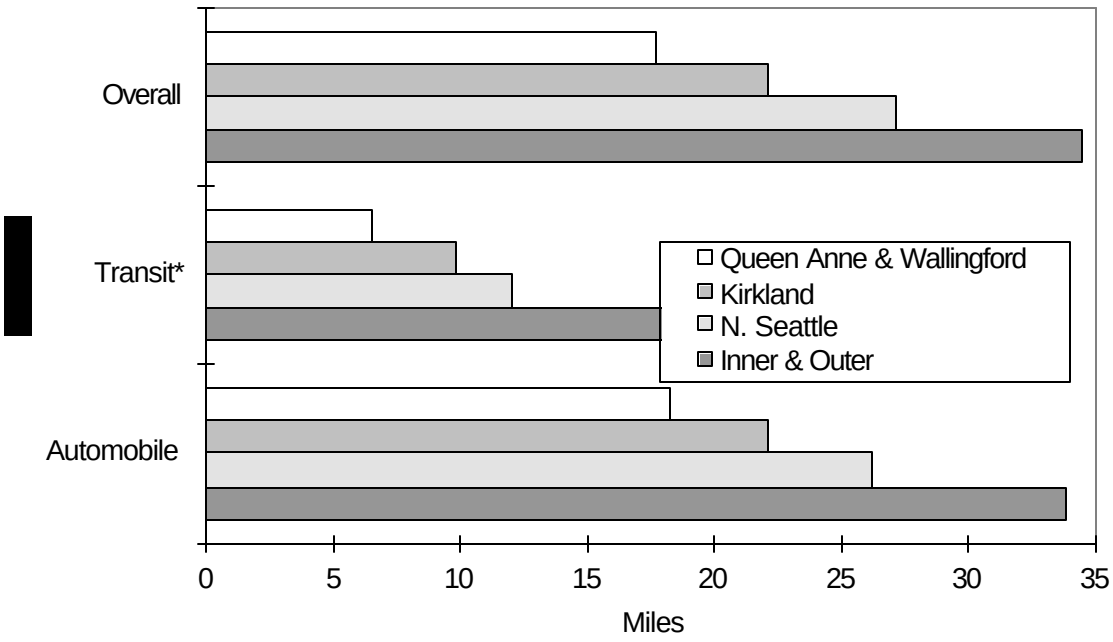


Figure 4. Total Personal/Recreation Trips by Walking Related to Household Distance from Commercial Streets



* Total mileage, for all modes, where a household member used transit

Figure 5. Average Total Daily Mileage by Mode (Weekdays)

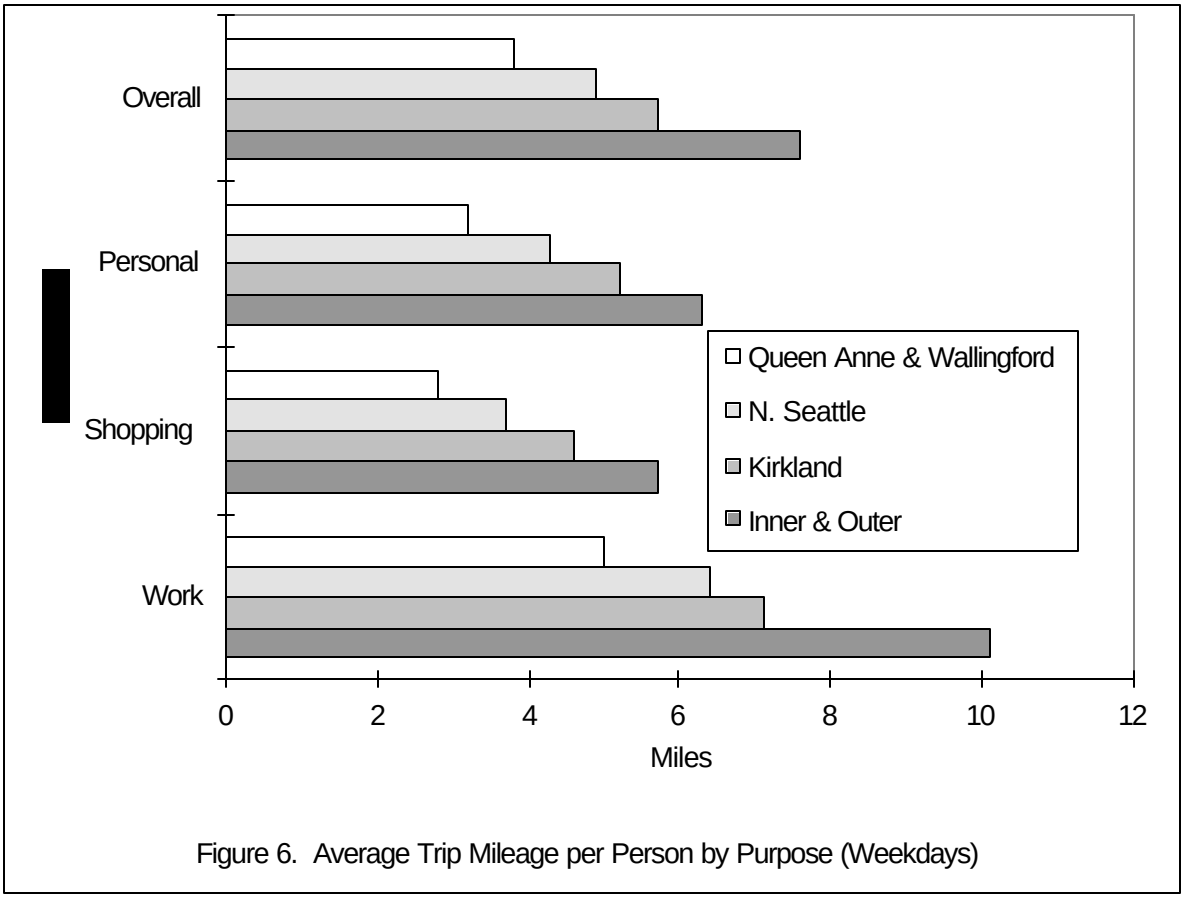


Figure 6. Average Trip Mileage per Person by Purpose (Weekdays)

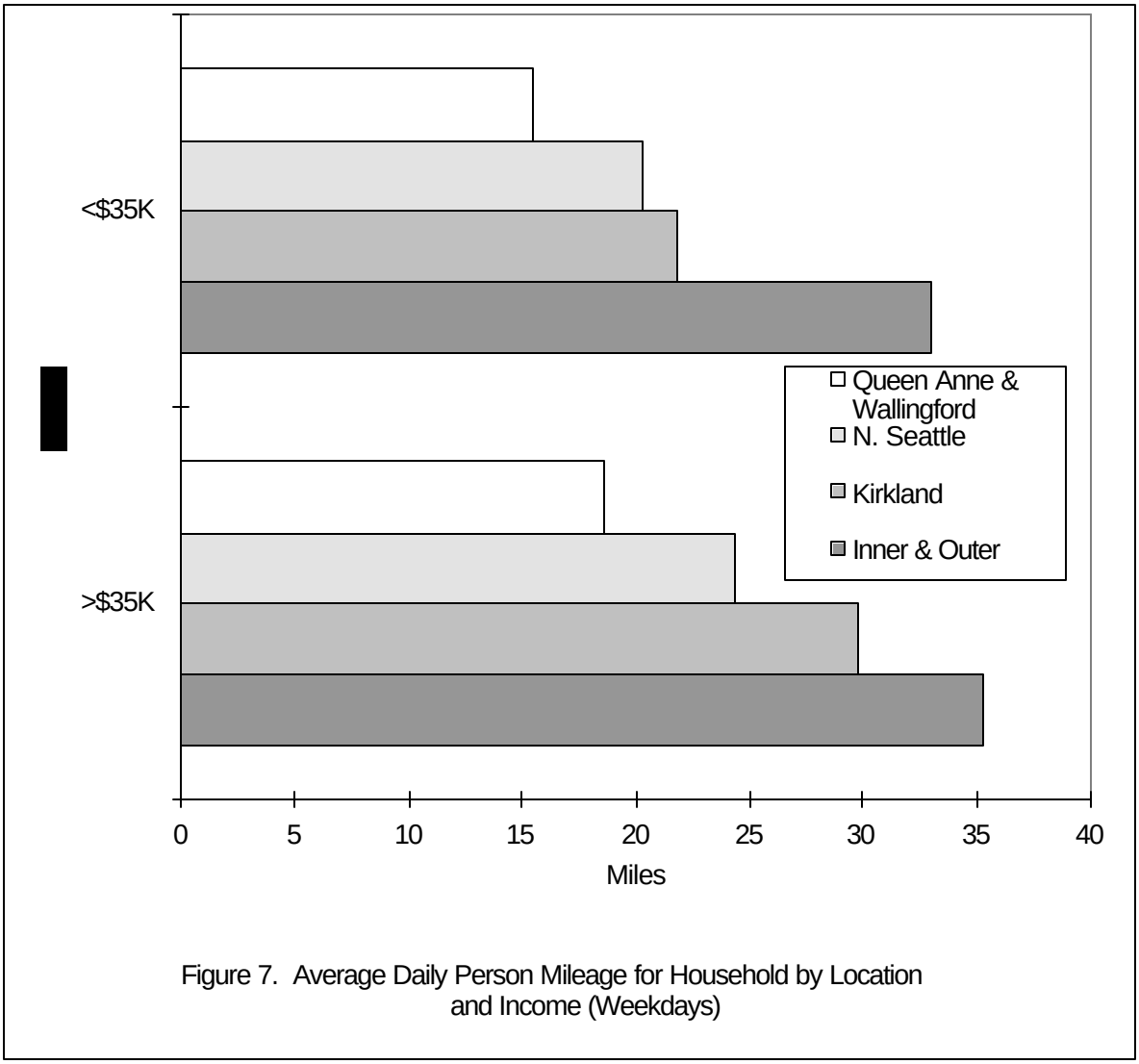


Figure 7. Average Daily Person Mileage for Household by Location and Income (Weekdays)

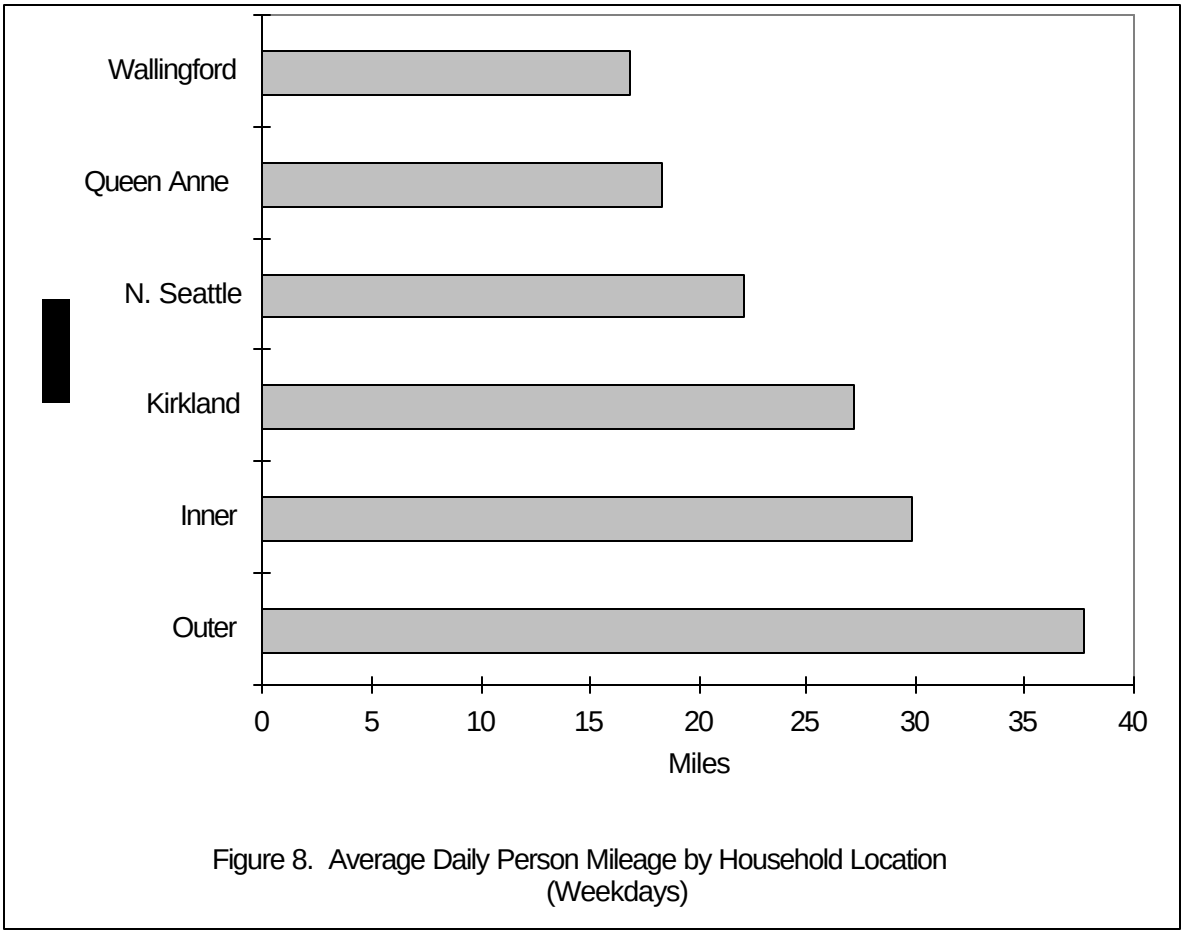


Figure 8. Average Daily Person Mileage by Household Location
(Weekdays)

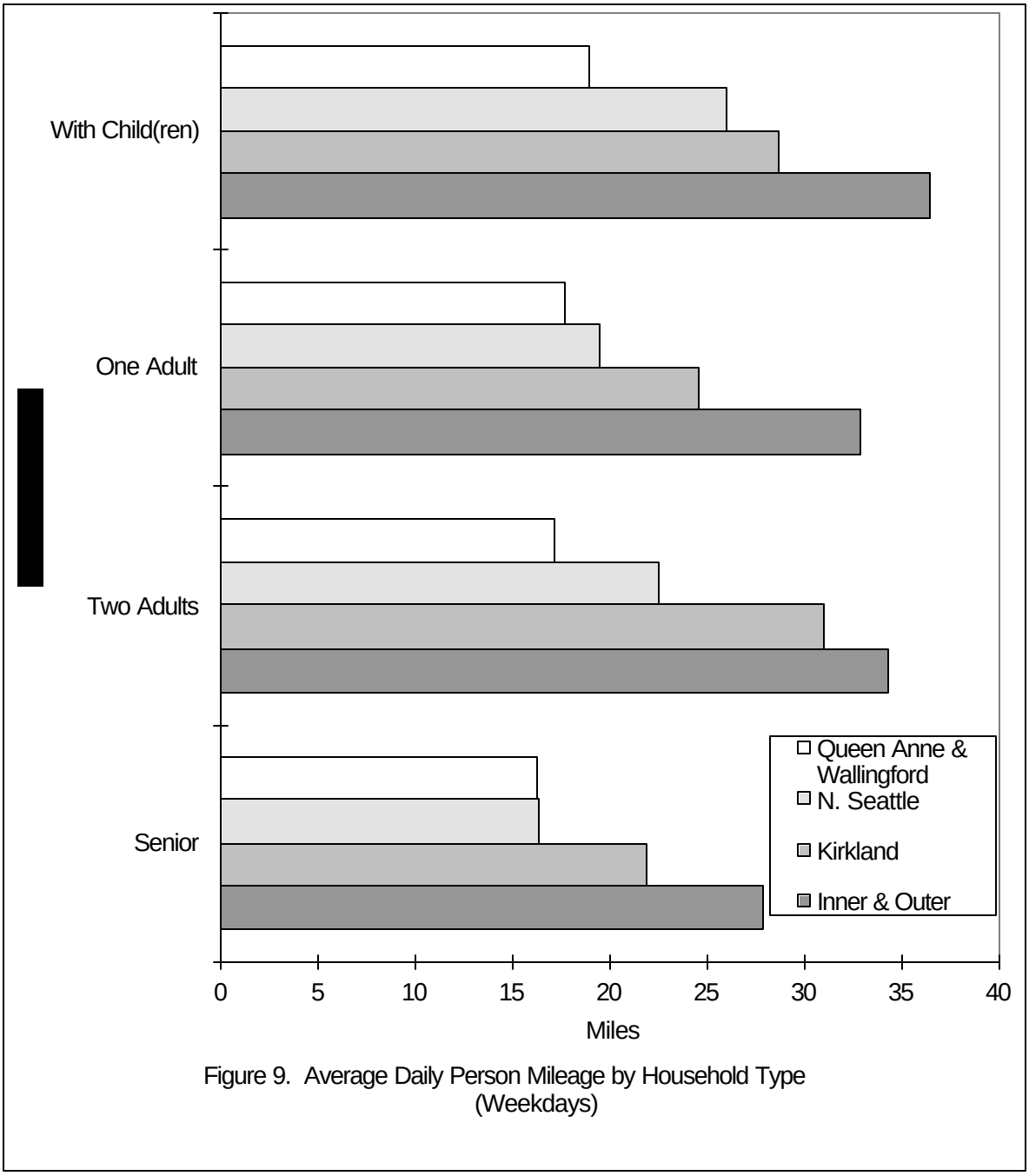


Figure 9. Average Daily Person Mileage by Household Type (Weekdays)

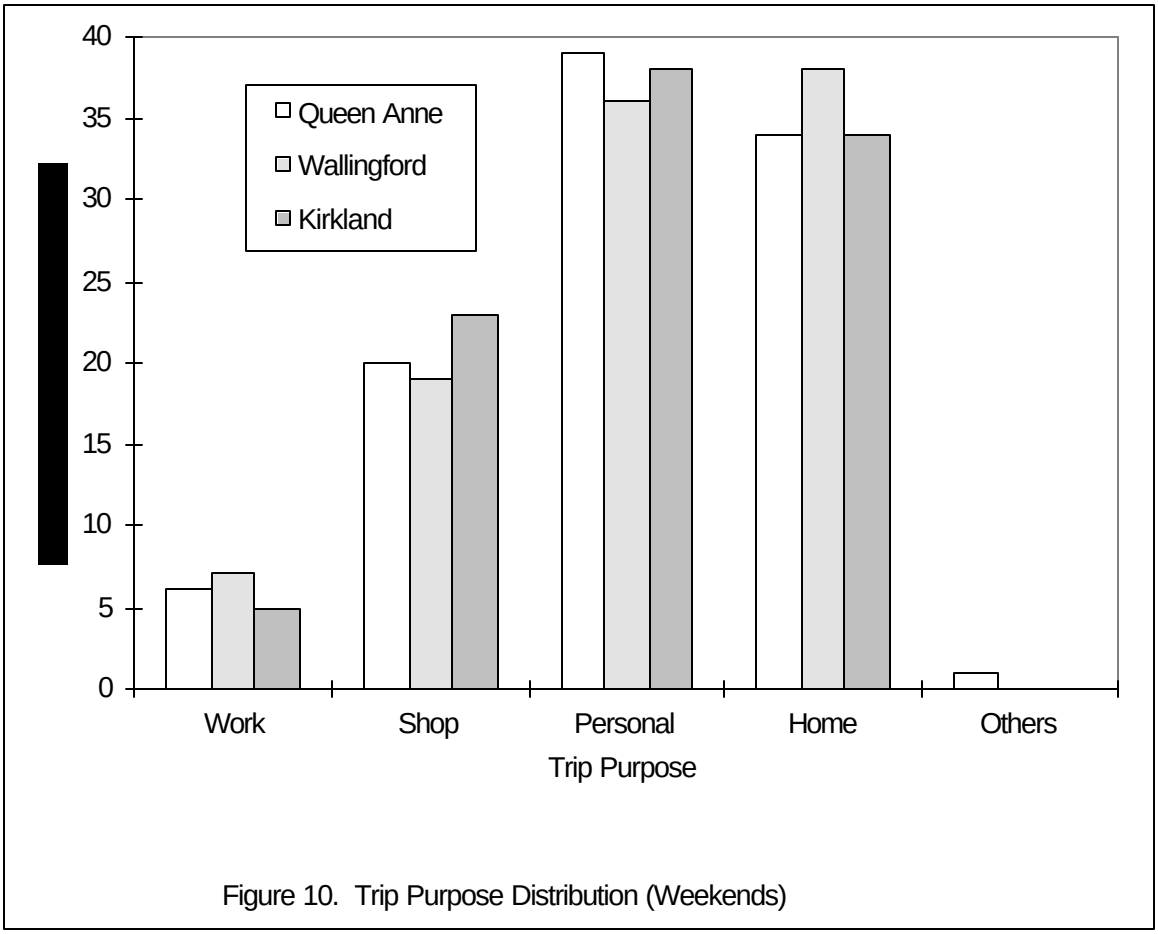


Figure 10. Trip Purpose Distribution (Weekends)

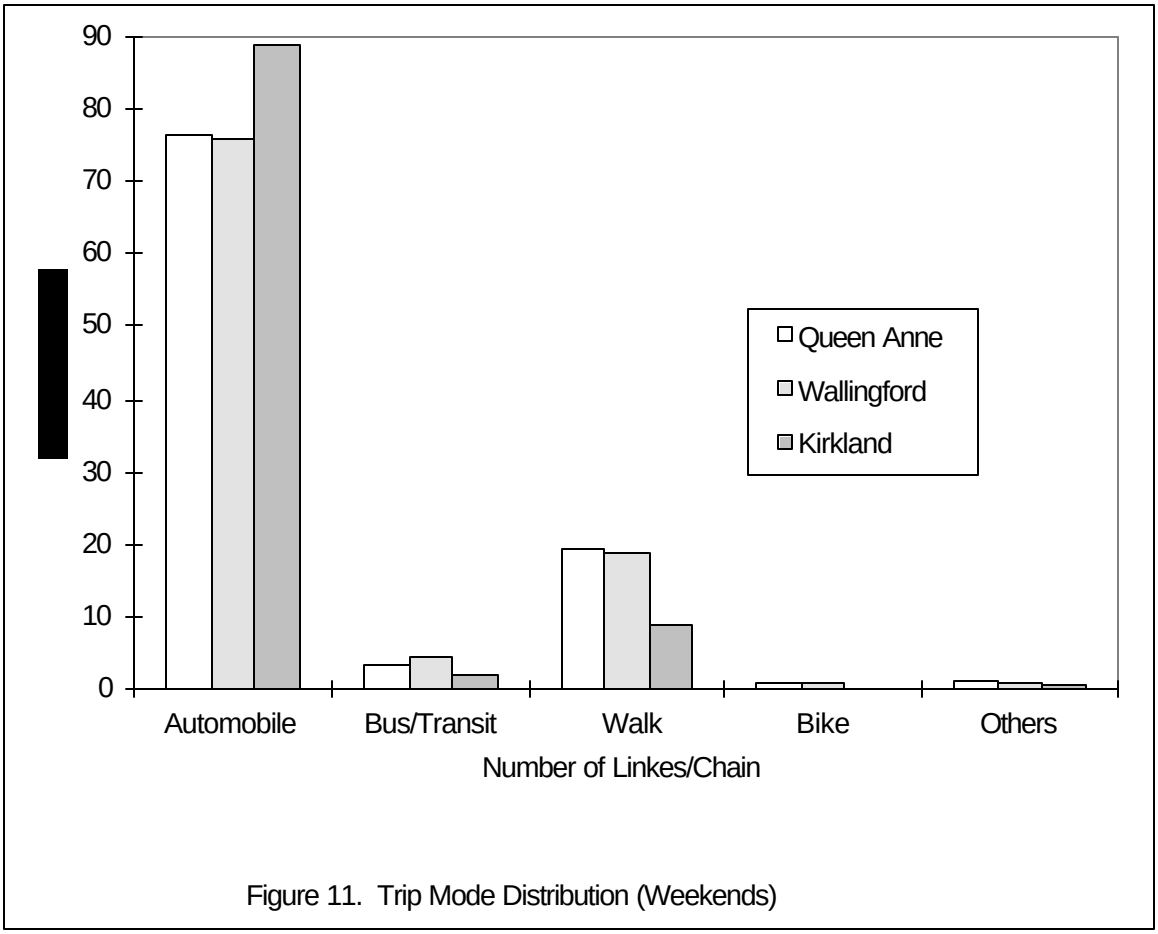


Figure 11. Trip Mode Distribution (Weekends)

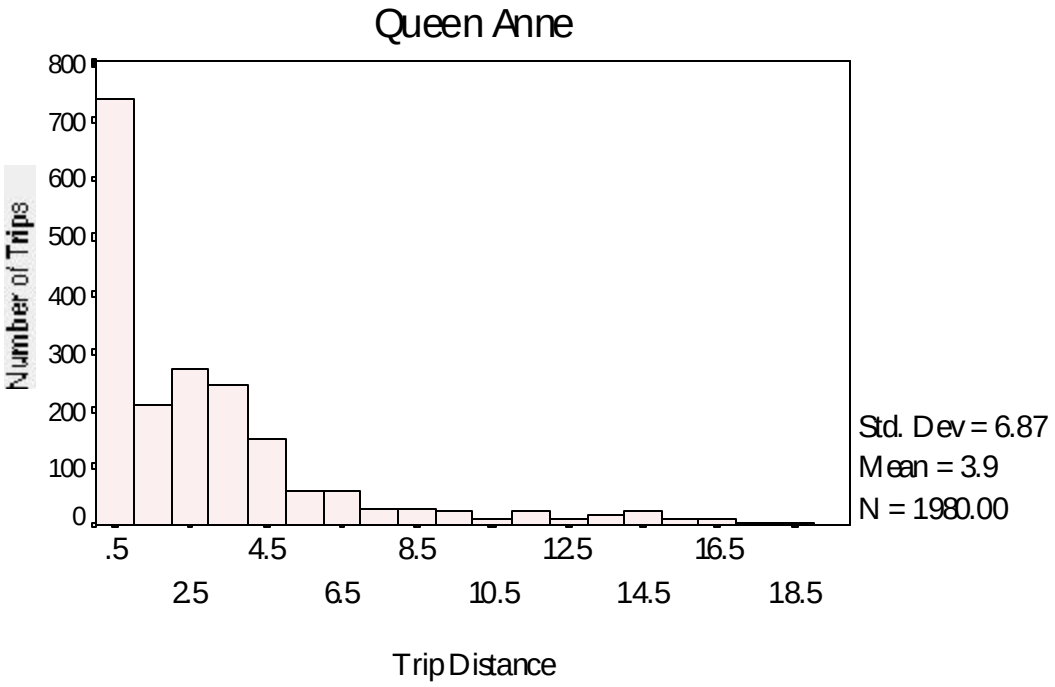


Figure 12. Trip Length Histogram - Queen Anne (Weekends)

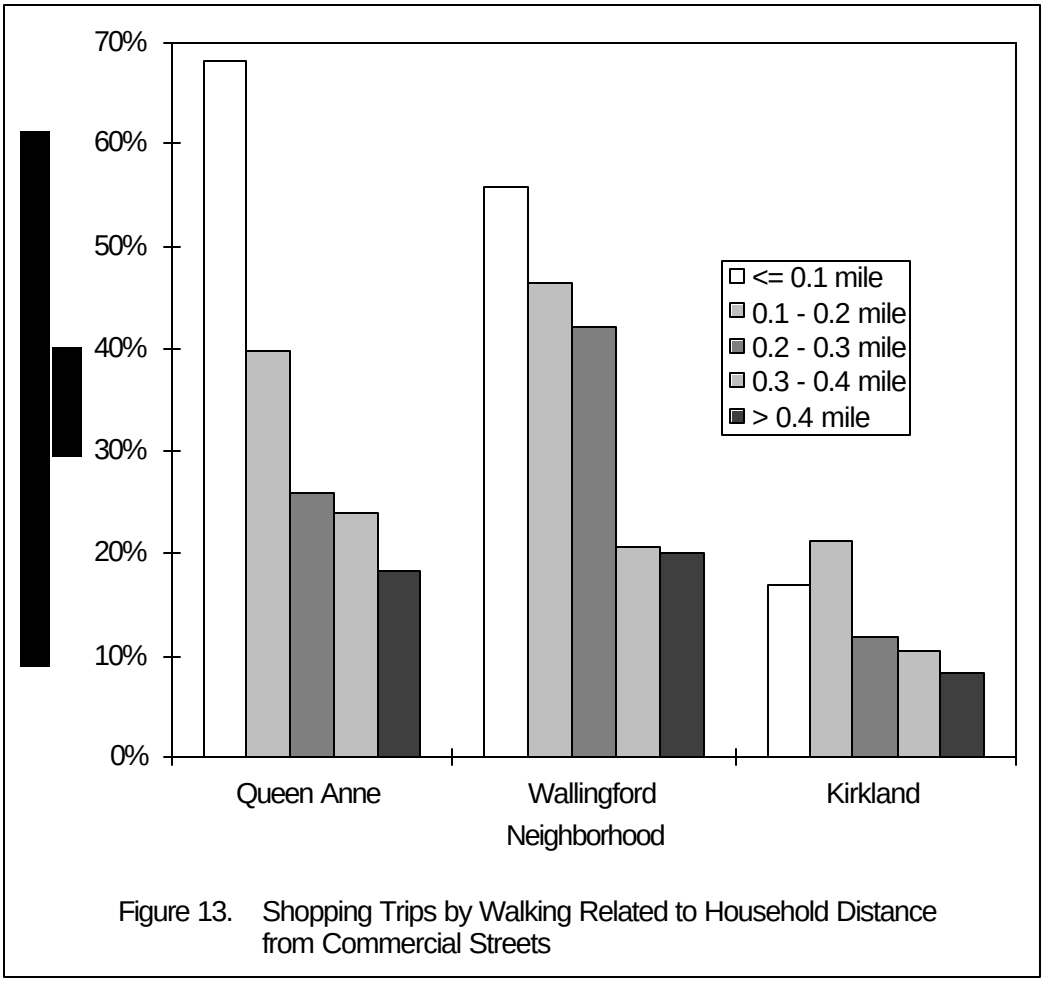


Figure 13. Shopping Trips by Walking Related to Household Distance from Commercial Streets

Figure 13. Trip Length Histogram - Wallingford

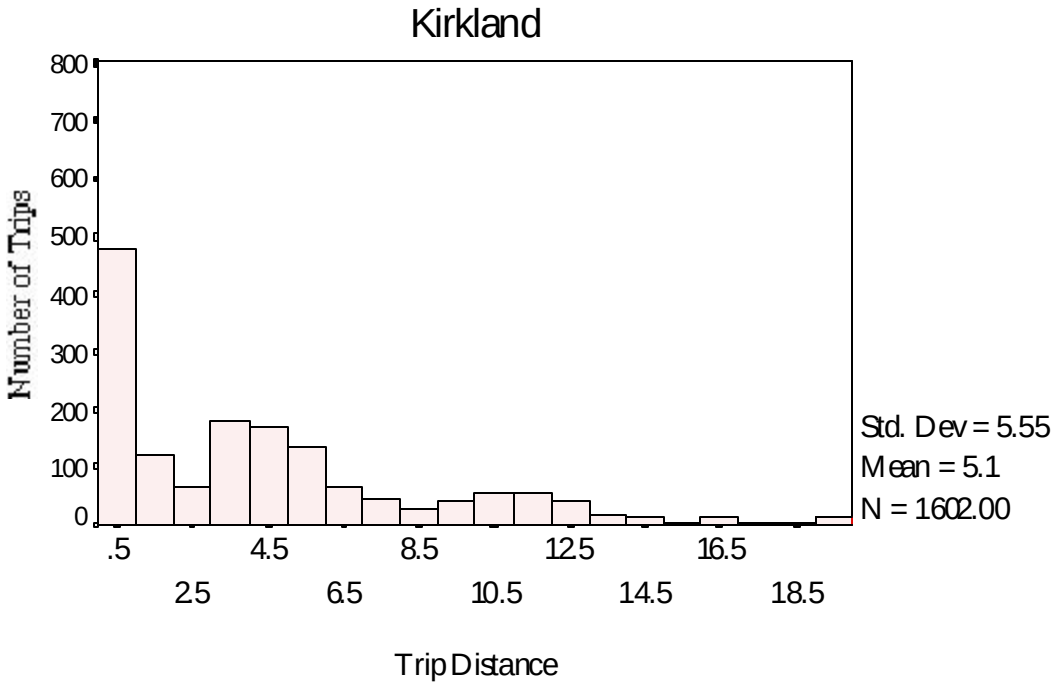


Figure 14. Trip Length Histogram - Kirkland (Weekends)

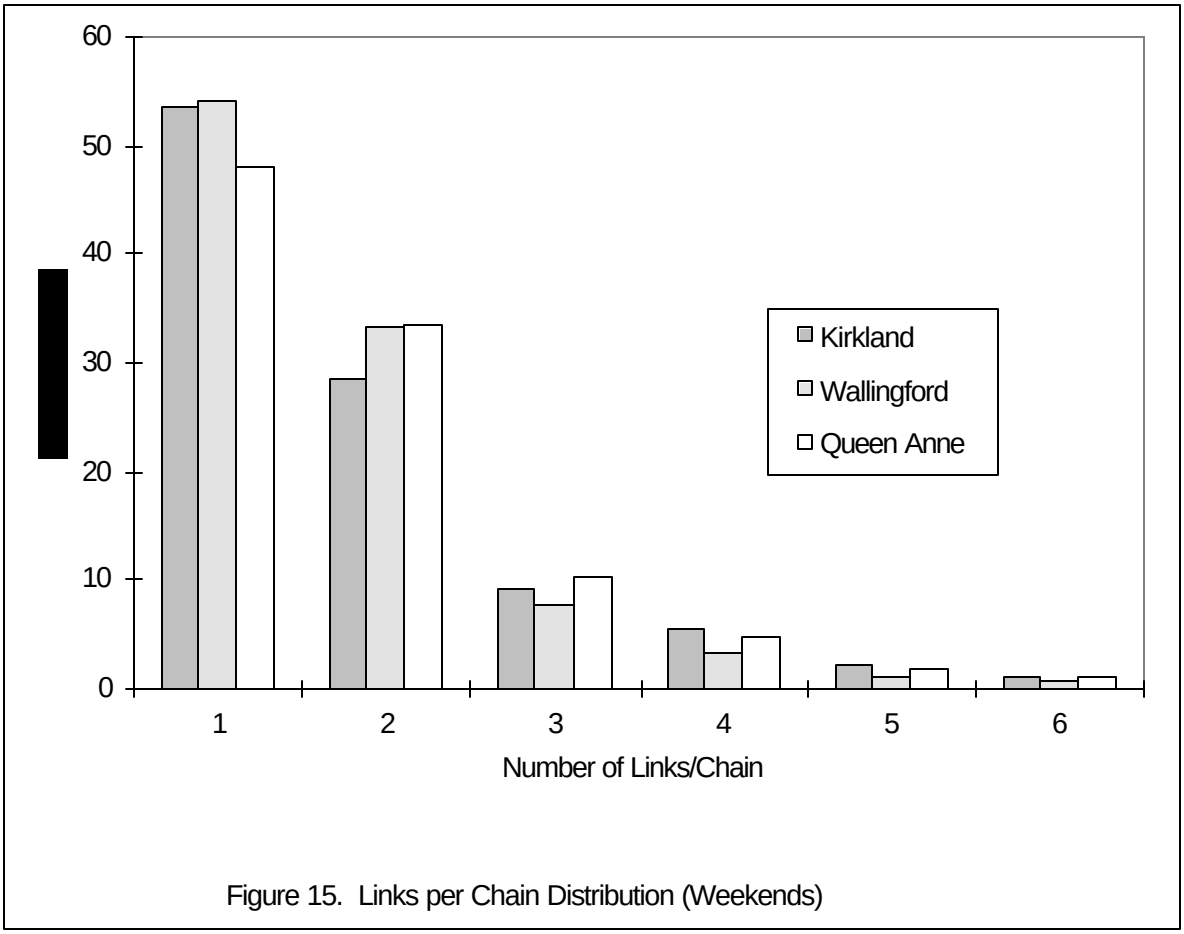


Figure 15. Links per Chain Distribution (Weekends)

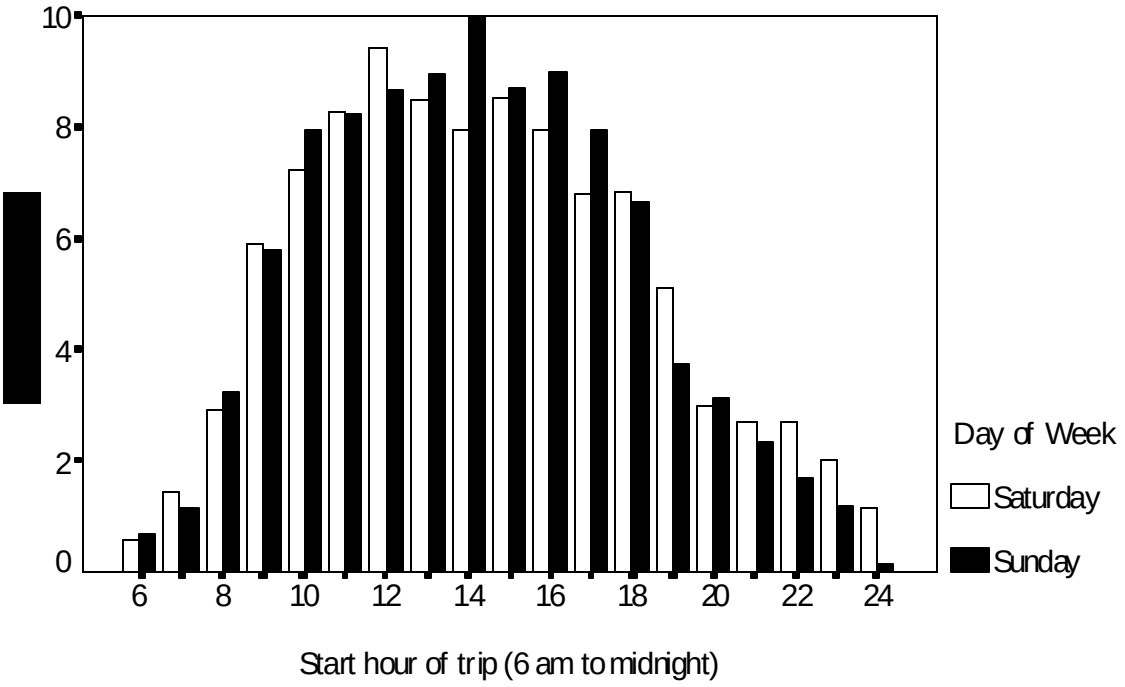


Figure 16. Hourly Distribution by Time of Day

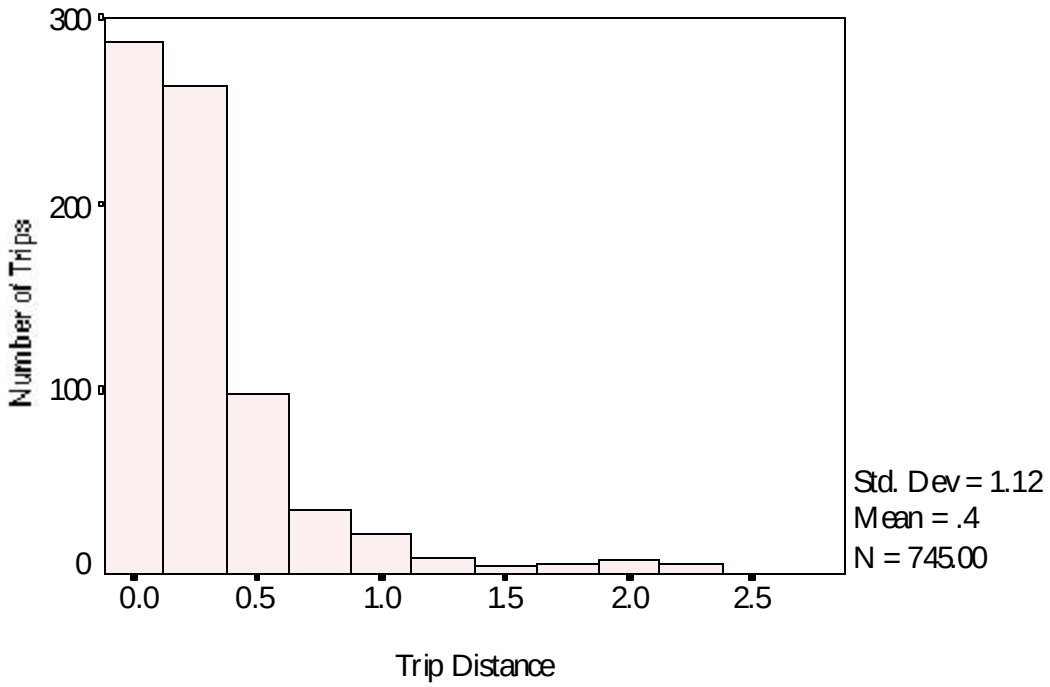


Figure 17. Trip Length Histogram for Walk Trips (Weekends)

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