# Travel Behavior, Environmental, & Health Impacts of Community Design & Transportation investment


# LUTAQH

## A Study of Land Use, Transportation, Air Quality and Health in King County, WA

**Final Report – December 2005**

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## Acknowledgements

Foremost, we would like to thank King County Executive Ron Sims for his vision and leadership in sustaining and creating healthy communities in King County and to the nearly tireless members of the LUTAQH Advisory Committee (see below). The authors would also like to acknowledge our project managers Don Ding and Karen Wolf for their considerable enthusiasm, leadership, and guidance in this effort. We would like to thank Don and Karen for their genuine good spirit and their passion for developing ways to apply this research within the County's many planning functions. It is their efforts that are to be largely credited for the level of interest in this study. We are indebted to Dr. Gary Molyneaux, who secured the LUTAQH grant for the County. We would like to thank Kelli Cain and Dr. Terry Conway with San Diego State University for their assistance with the collection of travel data and data analysis. We thank the National Heart, Lung, and Blood Institute of the National Institutes for Health who funded the Neighborhood Quality of Life Study which provided the health data used in this study. Other individuals contributing resources or assistance to the Study include Barbara McCann, McCann Consulting, Steve Winkelman and Greg Dierkers, Center for Clean Air Policy, Kathleen Kern, University of Washington. We would like to thank the Group Health Cooperative, the University of Washington, the Robert Wood Johnson Foundation, the Centers for Disease Control and Prevention, the Puget Sound Regional Council, the Transportation Choices Coalition, the Bullitt Foundation, and the cities of Kent and Redmond for their assistance with this project.

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# Table of Contents

# List of Tables

# List of Figures

# APPENDICES

# Executive Summary

***"Change is Inevitable. In a Progressive Country, Change is Constant."***
—Benjamin Disraeli, 1867

## Overview

Disraeli's wisdom of over 138 years ago demonstrates the need to regularly reevaluate what we do. King County is doing just that – re-evaluating how the county grows and how that growth affects the lives of county residents. King County undertook the Land Use, Transportation, Air Quality and Health Study (LUTAQH) to measure how specific land use and transportation actions affect air quality, mobility and congestion, and public health. The ultimate goal of the study is to guide the allocation of resources in King County as it works to reduce automobile dependency, increase transportation efficiency, improve air quality, and improve the health of county residents. This research documents the impact of land use decisions and transportation investments and suggests strategies for allocating resources to encourage more compact, mixed use neighborhoods with more transportation choices.

## LUTAQH's Role

King County is the first local government to fund a study of this kind – a study that explores the links among the built environment, mobility, air quality and public health. These study findings will be used to inform policy and investment decisions. Through its collaboration with the Neighborhood Quality of Life Study (NQLS, funded by the National Institutes of Health), LUTAQH is one of the first studies to comprehensively examine land use, transportation, air quality, and health as part of a single effort.[1] LUTAQH establishes a baseline of existing measures of land use, transportation investment, travel choices, and explores how these factors are associated with air quality, climate change and health.

## Key Findings

1. Whether the goal is to increase transportation efficiency, reduce automobile dependence, or reduce ozone and improve regional air quality and health, LUTAQH shows that compact development, a wide variety of land uses close to home and work, and a connected street network with pedestrian facilities can help achieve all of these goals.[2]

2. Residents walk more in neighborhoods that provide a wide variety of retail services, and where connections to such services are facilitated through an interconnected street network.

1 LUTAQH was modeled after the Atlanta based SMARTRAQ program (see www.act-trans.ubc.ca).

2 Each of the analyses conducted controlled for sociodemographic considerations and were significant at the 95% (P=.05) confidence level.

3. Transit and walking are highly synergistic — transit use was observed to be the highest in locations where walking was the most prevalent. Conversely, the choice to walk is highest where transit's convenience and efficiency is greatest.[3]

4. Residents in the most interconnected areas of the county travel 26 percent fewer vehicle miles per day than those that live in the most sprawling areas of the county.

5. Increased residential density, street connectivity, and land use mix near home and work are associated with significantly lower per capita vehicle emissions - in particular, fewer oxides of nitrogen (NOx) and volatile organic compounds (VOCs), which react in sunlight and form harmful ozone, as well as fewer greenhouse gas emissions, which contribute to global warming.

6. Residents of the most walkable areas of King County were less likely to be overweight or obese and more likely to report being physically active. Preliminary results suggest that residents of the most walkable communities within the county are more likely to meet the 30 minutes per day of moderate activity recommended by the U.S. Surgeon General[4].

## Conclusions

The results of LUTAQH clearly show that encouraging compact, mixed use developments that offer transportation choices will help King County meet its adopted goals of increasing transit efficiency, reducing automobile dependency, and improving air quality and health. To achieve its goals, the County must coordinate and integrate its decisions to invest and allocate resources and services. Actions that span transportation, land use, environment and health are required to bring about more sustainable, health promoting approaches to community design.

LUTAQH found that communities already exhibiting some of these attributes are delivering benefits to their residents in the form of less automobile dependency, more opportunities to be physically active and healthier and better air quality at the regional scale. These neighborhoods exist because in the past there was investment in compact neighborhoods with well-connected street networks, a mix of uses, and an orientation to transit.

Creating such communities is complex and requires many interlocking strategies, but King County is in a good position to reallocate its resources and become a national leader in making its neighborhoods more livable.

3 These are the same locations with higher residential and employment densities where transit service is more cost effective.

4 Results from the LUTAQH Study will be released in a peer-reviewed paper in the Journal of the American Planning Association this winter. Results presented above were released in a peer-reviewed paper presentation at the Society of the Behavioral Medicine Conference in March 2004.

## Recommendations

Federal, state, and local laws and policies have put King County in a strong position to act on the findings of this report. Federal transportation and air quality laws require the creation of plans that meet air quality standards and provide transportation choices. The Washington State Growth Management Act established Urban Growth Areas to focus metropolitan growth and to coordinate land use and transportation actions. The King County Comprehensive Plan supports mixed-use developments, non-motorized modes and the reduction of single-occupancy vehicle travel. The allocation of resources to projects and services plays a significant role in the formation of our communities and transportation system.

LUTAQH suggests additional actions and policies that can further King County's goals. Activities related to measuring, planning, and implementing the recommendations of this study are identified. Specific initiatives in targeted neighborhoods are recommended. Many of the actions are completely within the County's sphere of influence because the County has regulatory or fiscal mechanisms in place; the County can monitor its own performance in achieving a goal pursuant to a given strategy. Other actions will require cooperation and partnerships with other jurisdictions.

## Study Approach

A group of stakeholders representing diverse backgrounds and expertise worked with the project team to compare residents' travel patterns, automobile emissions, physical activity levels, and body mass index (BMI) in different types of neighborhoods. The team collected detailed, parcel-level data on land use and data on transportation connections in neighborhoods across King County. This data was matched with information on residents' travel habits and physical activity collected by the Puget Sound Regional Council (PSRC), the National Institutes for Health Neighborhood Quality of Life Study, and Group Health Cooperative (Silver Sneakers data). A total of 3,200 households were included in the main portion of the PSRC study. The NIH and Group Health studies were used to apply health, attitudinal and age-related travel characteristics to the household population of the LUTAQH study.

The researchers examined the neighborhood surrounding each household, determining the area within a one-kilometer walk of the home. In many cases this area (known as the network buffer) was considerably smaller than a one-kilometer 'crow-fly' distance because of the limitations of the street network, as shown in Figure A. The researchers then evaluated the characteristics of this area for each household to see how many and what types of destinations residents could reach within one kilometer of home. This information was used to discover the relationship between land use and travel choices.

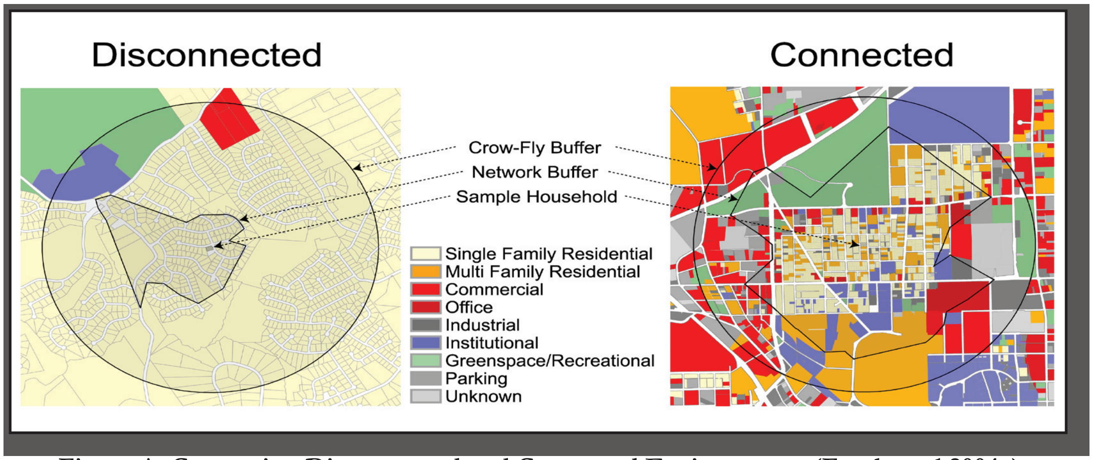


**Figure A: Comparing Disconnected and Connected Environments (Frank et al 2004a)**

Figure A shows how neighborhood settings can affect transportation choices. The household in the center of the neighborhood on the left is located in a spread-out ("sprawling") area with few shops and businesses within a walkable distance. The lack of through streets in this neighborhood and the presence of arterials with many lanes and inadequate sidewalks severely limits the destinations residents can reach within one kilometer of their home. The household on the right is located in a more connected grid street network with different types of destinations within one kilometer, including shops, institutions, and parks. Such neighborhoods usually also have better sidewalks and pedestrian connections.

Integration of this land use information with the travel and health databases enabled researchers to look for relationships between the physical design of the environment where people live and work, and their reported travel, physical activity, and demographic characteristics. This data also allowed researchers to measure vehicle emissions, including ozone precursors and greenhouse gases. Emissions were estimated for each reported trip and then correlated with the land use characteristics of the areas where participants lived and worked. Figure B shows an example of a regional trip.

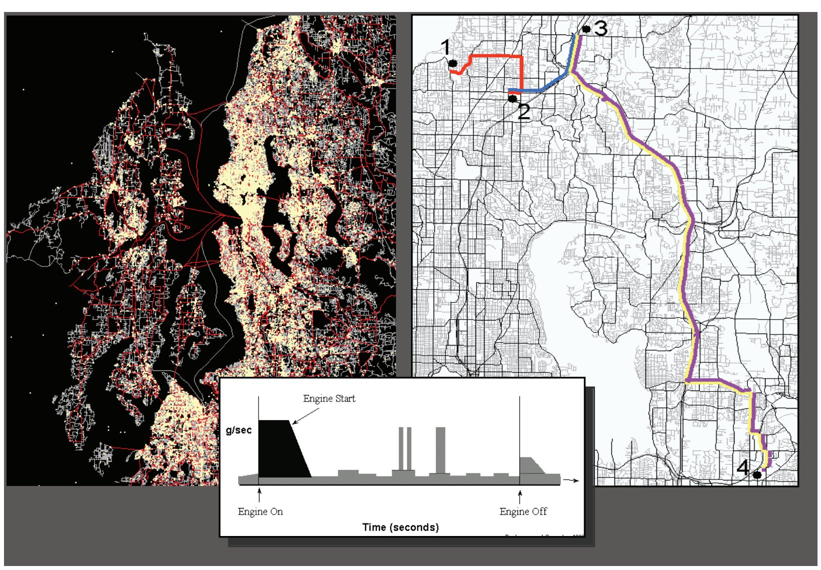


**Figure B: Estimating Vehicle Emissions – regional trip and LANDSAT photo**

(Source: Dr. William Bachman, GeoStats)

Additionally, three communities (White Center, Redmond, and Kent East Hill) were examined as part of the LUTAQH study. Applying the study results to real communities increased the usefulness of the research for the development of policies that support transit and nonmotorized travel. The researchers applied the findings to make specific recommendations for improving health, air quality and transportation outcomes in these communities, thereby demonstrating the LUTAQH project's potential benefits.

## What We Found

On a per capita basis, as compared with more sprawling communities, higher-density residential neighborhoods with mixed land uses and a connected street network are associated with:

- less auto use,
- less air pollution,
- fewer greenhouse gas emissions,
- less energy consumption[5],
- more transit ridership, walking and
- overall physical activity, and
- lower levels of obesity[6].

These outcomes are consistent with many of the goals of the King County Comprehensive Plan. To further encourage these outcomes, the County's resource allocations, development regulations, and related policy actions should be consistent with the goals in the Comprehensive Plan, with the requirements of Washington's Growth Management Act and with actual growth/development (Frank et al 2005a). This study shows what actions the County might take to further its goals of reducing auto dependency, increasing transportation choice and efficiency, and improving air quality and residents' health. The following sections outline these findings.

### Transportation Efficiency and Choice

Transportation efficiency is best served by helping people travel shorter distances, with more opportunities to ride public transit, walk, or bicycle. The potential to change travel patterns in King County is enormous — 42 percent of trips in the county are three miles or less, mostly distances easily traveled on foot or bicycle. Yet of the 16 percent of trips that are less than one mile, 43 percent

5 Energy consumption is inferred from the greenhouse gas emissions models which are based on fuel combustion rates.
6 Increased obesity is associated with higher likelihoods of cardiovascular disease, type II diabetes and colorectal cancer.

are currently made by automobile drivers. The LUTAQH study found that mixed land uses – the commingling of homes with offices, shops, schools, parks, and other destinations – matters most when it comes to transportation efficiency. While residential density is needed to sustain commercial use and to make transit viable, providing retail destinations and activities near where people live and work is also critical.

## Walking

The LUTAQH research found that residents walk more in mixed-use neighborhoods with good street connections. The land uses most strongly linked to the percentage of household trips made on foot proved to be educational facilities, commercial office buildings, restaurants and taverns, parks, and neighborhood-scale retail establishments, with civic uses and grocery stores following closely. Having establishments such as these within a kilometer of one's home allows them to meet their recommended physical activity needs by walking. Data showed the odds of walking increased by 20 percent for each additional park and 21 percent for each additional educational facility that were within a one kilometer walking distance of King County households. It is anticipated that this relationship is "non-linear" and that smaller increases in walking will likely result as demand for parks and schools is approached and met.

When controlling for demographics, LUTAQH found that each quartile increase in:

- the number of intersections per square kilometer (intersection density) corresponded with a 14 per cent increase in the odds of walking for non-work travel;
- residential density levels corresponded with a 23 percent increase in the odds of walking for non-work travel;
- the number of retail establishments corresponded with a 19 percent increase in the odds of walking for non-work travel.

In terms of observed walking patterns, this study finds that the actual number of recreational, educational, retail, entertainment, and other commercial attractions near one's home appears to be more important than the size of the attraction itself. This is an important finding, suggesting that more small destinations interwoven in residential areas is the best way to encourage walking for errands and other non-work purposes. For example, a big box store does not affect walking as much as several smaller shops with the same total square footage. The likelihood of walking increases the most when a number of these factors are combined:

- a variety of destinations close to home
- greater street connectivity (intersection density)

- greater residential density

## Transit

LUTAQH discovered a synergistic relationship between transit use and neighborhood walkability, observing increased transit ridership in the same locations where walking was also more prevalent. Neighborhoods with a greater mix of land uses, better street connectivity, and higher density supported both transit use for regional mobility and walking for nearby destinations. Whereas the number of non-residential destinations did the most to influence walking rates, the total square footage of commercial destinations in the neighborhood had the strongest relationship with transit use.

Thirty-two percent of transit trips are for the work commute. The choice to commute by transit was strongly influenced by the design of the neighborhoods that surround both home and work. Distance to bus stops or stations also was an important predictor of transit use. In this study, the odds of someone reporting a transit trip to work decreased by 16 percent with each 1/4 mile increase in the distance to transit from home and by 32 percent with each 1/4 mile increase in the distance to transit from work. Each additional vehicle per household was associated with a 45 percent decrease in the odds of taking transit to work. This is undoubtedly influenced by the comparative time savings associated with auto use over transit. In many parts of the county it takes as much as three times longer to get to a major urban destination using transit as opposed to driving.

Not surprisingly, the land uses most closely associated with higher percentages of work trips on transit are also those associated with typical downtown areas: more commercial office floor space, more retail floor space and a greater number of large retail attractions and office buildings. Areas that included predominantly fast food outlets, high tech companies, office parks and vacant land were found to be associated with lower transit ridership. One of the best indicators of transit use was the cost of parking and the level of employment density at the work trip destination, which are directly related to typical downtown areas (parking charges and high employment density) and suburban development (no parking charges and lower employment density).

All of the relationships found between transit use and urban form controlled for household size, income and number of household vehicles.

## Automobile Dependency

Clearly where people are walking more and taking transit more frequently, they are driving less. Automobile dependency, as measured by vehicle miles traveled (VMT), decreased in neighborhoods with higher residential density and better street connectivity. The typical person surveyed drove an average of 29 miles per day, but the variation between persons was quite large. Compactness, the mix of land uses close to home, and a high retail floor area ratio (density) were important factors linked to driving fewer miles. The results suggest that certain combinations of land uses can work synergistically to enable people to drive less.

A highly mixed land use pattern allows residents to accomplish a variety of activities within a small area without a car. Places where driving was lowest had more schools, grocery stores, civic space, and more rentable space for doctors and dentists and other professional services. While the absolute number of non-residential destinations was most important, having more floor space devoted to commercial offices and neighborhood retail also was associated with less driving.

Fewer vehicle miles of travel (VMT) were observed for residents located in areas with greater residential density, land use mix, street connectivity, and retail floor area ratio as shown in Table 1.

| Urban Form Factors | controlling for gender, income, age, education, total number of household vehicles, distance to nearest bus stop | | | |
|---|---|---|---|---|
| | Quartiles of Urban Form Variables | | | |
| | 1 | 2 | 3 | 4 |
| Retail Floor Area Ratio | 30.16 | 30.48 | 30.50 | 25.57 |
| Intersection Density | 34.03 | 28.83 | 30.01 | 25.46 |
| Residential Density | 29.77 | 29.14 | 28.13 | 27.17 |
| Mixed Use | 32.26 | 30.38 | 27.94 | 27.15 |

**Table A - Vehicle miles traveled across urban form factors**[7]

The greatest differences in VMT were observed across levels of street connectivity (intersection density) where the average VMT was 34 miles per person in the least connected street networks and 25 miles in the most connected street networks in King County. This represents 26% fewer vehicle miles of travel for residents who live in communities that have the most interconnected street networks in the county. With a more connected street network and shorter blocks, more direct and shorter routes can be chosen. Increases in retail and residential density and a greater mix of uses mean more destinations nearby. The combination of more direct routes and closer destinations can decrease travel distance for all modes and make walking, bicycling and transit more convenient and viable.

More research will be helpful in further gauging which combinations of uses are the most synergistic in reducing auto reliance for specific types of trips. Interestingly, not all commercial uses were associated with lower vehicle miles of travel. Neighborhoods with more convenience stores and fast food restaurants were linked with higher VMT. This is believed to be a function of the environment in which these uses are located, rather than the uses themselves.

These analyses controlled for gender, income, age, educational attainment, number of vehicles, and distance to transit. That is, the results transcend household characteristics and were independent of those variables.

7 Quartile 1 is the lowest and 4 is the highest level for each urban form factor

## Air Quality

The travel data from the study allowed the researchers to estimate the pollutants emitted during both automobile and transit trips. The analysis focused on the two pollutants most associated with smog and harmful ozone formation — volatile organic compounds (VOCs) and oxides of nitrogen (NOx). At present, the region is more focused on strategies to reduce VOCs.

Increased residential density, intersection density, land use mix, and floor area ratio (retail square footage divided by land area in retail use) near home and work were all associated with lower per-capita generation of NOx and VOCs[8]. As shown in Figure C, significantly lower levels of VOCs are generated by households located in areas with more intersections per square kilometer – more intersections correspond with areas with higher levels of street connectivity and direct connections between residences and nearby destinations.

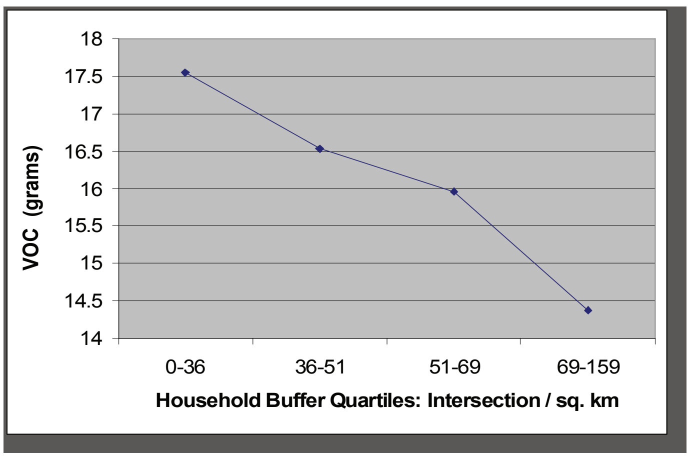


**Figure C: Volatile Organic Compounds & Intersection Density Where People Live (N=2,467)[9]**

Households with fewer than 36 intersections per square kilometer generated approximately 17.5 grams of VOCs per person per day, whereas those with more than 69 intersections per square kilometer generated about 14.4 grams of VOCs per person per day.

These analyses also investigated the relationships between VOC generation and the land use patterns where people work. Significantly lower levels of VOC generation were found for respondents working in areas with higher concentrations of retail activity. As shown in Figure D, the more retail square footage within a kilometer distance of work locations, the fewer VOCs they generate. This analysis suggests that about 150,000 square feet of retail use within one kilometer of where people work is required before significant VOC reductions are observed. For work environments, the total amount of retail space was

8 Emissions estimates assume that the traveler chose the shortest time-path for each trip taken to account for directional fluctuations in traffic congestion during peak periods. Speed estimates for each link were based on the congested flows from the Puget Sound Regional Council's (PSRC) travel model. Climatic and fleet mix inputs used by the PSRC and Puget Sound Clean Air Agency were accounted for as well. Speed based emissions rates were developed for cold starts and hot stabilized operation for each pollutant. For more information, please see the final report and technical appendices.

9 ANOVA controlled for gender, income, age, total number o f vehicles in the household. VOC differences across quartiles significant ($p<0.001$).

the best urban form predictor of VOC generation.

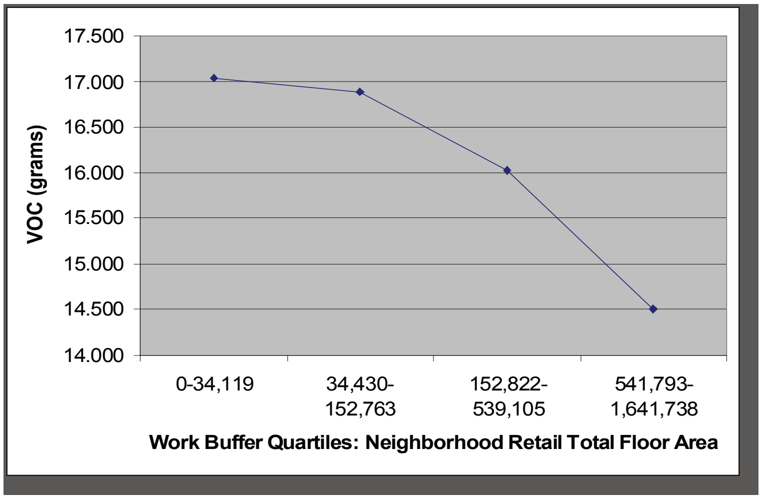


**Figure D: Volatile Organic Compounds and Retail Use Where You Work (N=2,467)**[10]

The research also showed street connectivity where people live appeared to be the most closely associated with the generation of oxides of nitrogen (NOx). Mean emissions of NOx declined from 29 to 23 grams per person per day, a 21 percent reduction, between residents of the least to the most connected environments[11].

## Climate Change

Vehicle emissions account for over 60 percent of greenhouse gases, a major cause of climate change, in the central Puget Sound region. Climate change has been associated with loss of snow pack, which in turn affects water supply during critical times of the year for salmon[12]. Climate change also has been associated with lower water reservoir levels in the Cascades in recent years and droughts are projected to worsen. Projections suggest that this could one day threaten our ability to meet the basic water needs of King County residents; water availability for irrigation and for hydropower is already impacted.

In collaboration with the Center for Clean Air Policy (CCAP), LUTAQH extended its assessment to include measures of greenhouse gas formation. CCAP partnered with King County on this study by providing funding through the Bullitt Foundation and technical assistance to develop speed sensitive estimates of carbon dioxide (CO2) production that could be used in the LUTAQH study. LUTAQH found that higher levels of land use mix, intersection density and residential density are associated with less greenhouse gas production on a per capita basis. Land use variables such as having retail close to

10 ANOVA controlled for gender, income, age, total number o f vehicles in the household. VOC differences across quartiles were significant ($p<0.001$).

11 Analyses are based on quartiles of each urban form variable and controlled for gender, income, educational attainment, number of household vehicles and network distance to transit (except for VOCs where distance to transit was not significant.) For more information, please see the final report and technical appendices.

12 VOCs are more associated with cold starts than NOx. This explains why they do not decline as much in association with increased levels of the urban form measures. Therefore, less VMT may be associated with less emissions overall, but increased numbers of short trips, that are often cold starts, generate more VOCs per unit of distance traveled.

home, intersection density, residential density and travel patterns including vehicle miles traveled (also a function of land use) explained about 24 percent of the variation in household level CO2 production. The study controlled for vehicle ownership, household size, and income. Results suggest that urban form influences CO2 indirectly through VMT, and directly through travel speed and engine operation (such as cold start functions). These results inform and support the Puget Sound Clean Air Agency's efforts to reduce greenhouse gas formation in the region through transportation-efficient land use strategies.

## Physical Activity and Health

LUTAQH studied the influence of urban form on health using data collected for the Neighborhood Quality of Life Study (NQLS – see www.nqls.org). Sixteen NQLS communities were selected across King County to represent low and high levels of walkability (as measured by land use mix, density, connectivity, and floor area ratio of retail) and low and high levels of income (socio-economic status - SES). These sixteen communities are shown in Figure E. Queen Anne, for example, is a high walkability and high income community shown in green, whereas Sammamish is a low walkability and high income community shown in red. Community selection was conducted at the census block group level where measures of walkability were matched with census data on income and ethnicity.[13] About 75 participants between the age of 20 and 65 were recruited from each community and their physical activity levels were measured objectively with a physical activity monitor.

13 The Neighborhood Quality of Life Study (NQLS) focuses on King County residents between the ages of 20 and 65 years of age and is led by Dr. James Sallis, Principal Investigator, and co led by Dr. Lawrence Frank and Dr. Brian Saelens.

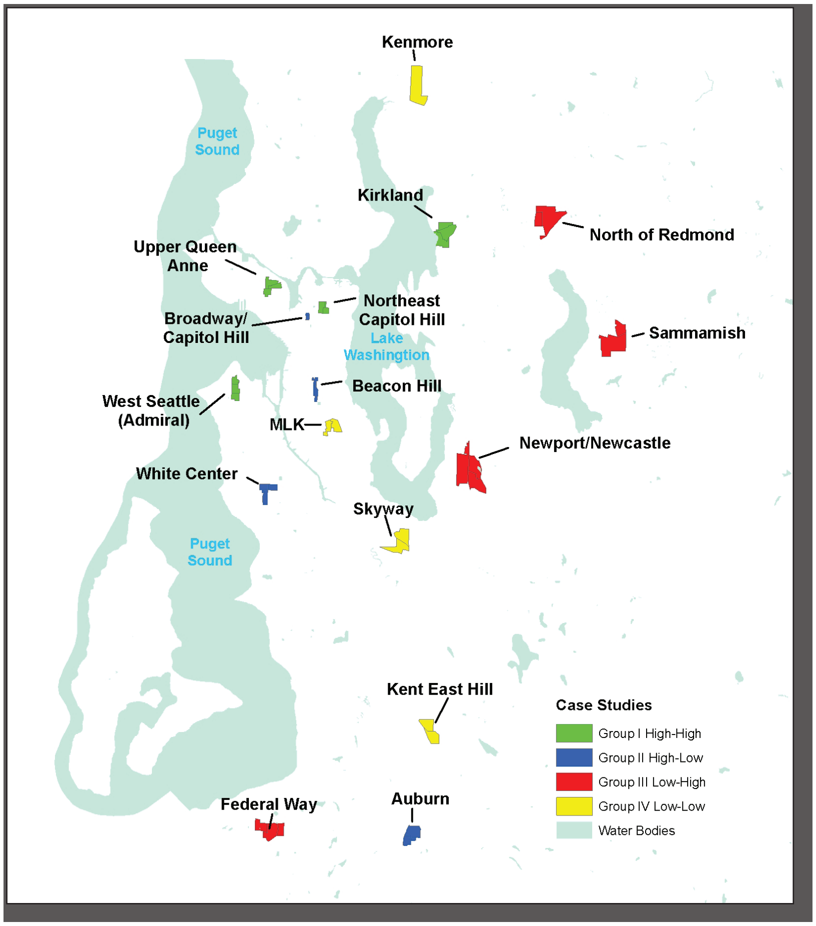


**Figure E: Sixteen NQLS Communities**

A higher proportion of participants in the more walkable communities (both low and high income) were found to achieve the U.S. Surgeon General's recommended 30 minutes of moderate and vigorous activity per day (see Figure F). For low-income (low SES) communities, the percent meeting the 30-minute threshold increased from 46 to 52 percent as walkability increased. For high-income (high SES) communities, the percent meeting the 30-minute threshold increased from 44 to 58 percent as walkability increased. Results presented across walkability are significant at the 95 percent confidence level when adjusted for age and gender.

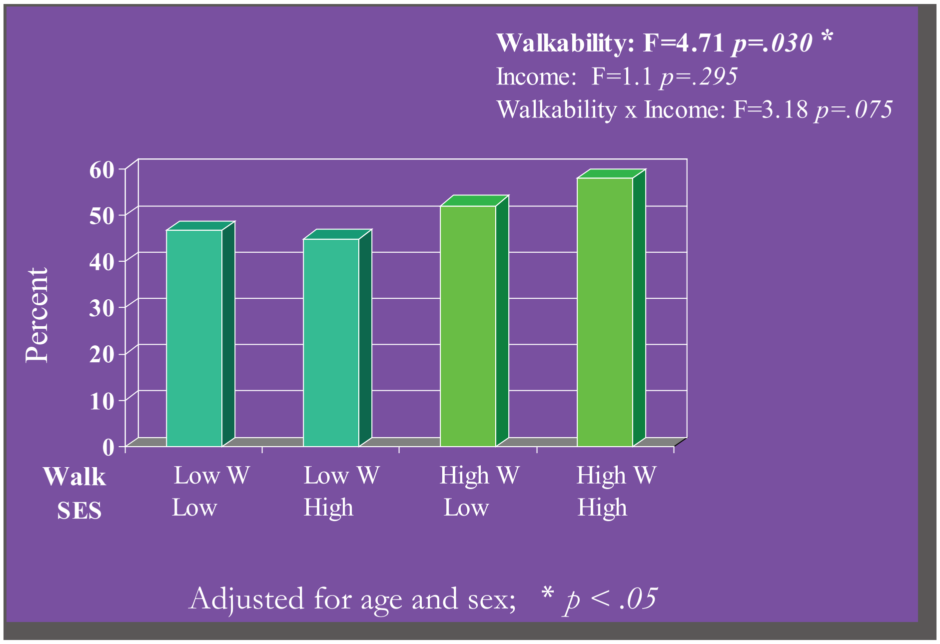


**Figure F: Percent Meeting 30 Minutes Per Day Guideline: Moderate and Vigorous Activity**

(from Neighborhood Quality of Life Study) (Note: W = walkability / SES = income)

Mean body mass index (BMI) was found to be lower in the more walkable communities, suggesting that a lower proportion of people in these more walkable communities are obese or have a BMI exceeding 30 (see Figure G). The results hold true when comparing residents of communities with similar income but differing levels of walkability. However, the most alarming results are found in the low walkability-low income communities, where the mean BMI of 27.5 is halfway between overweight (BMI = 25) and obese (BMI = 30).

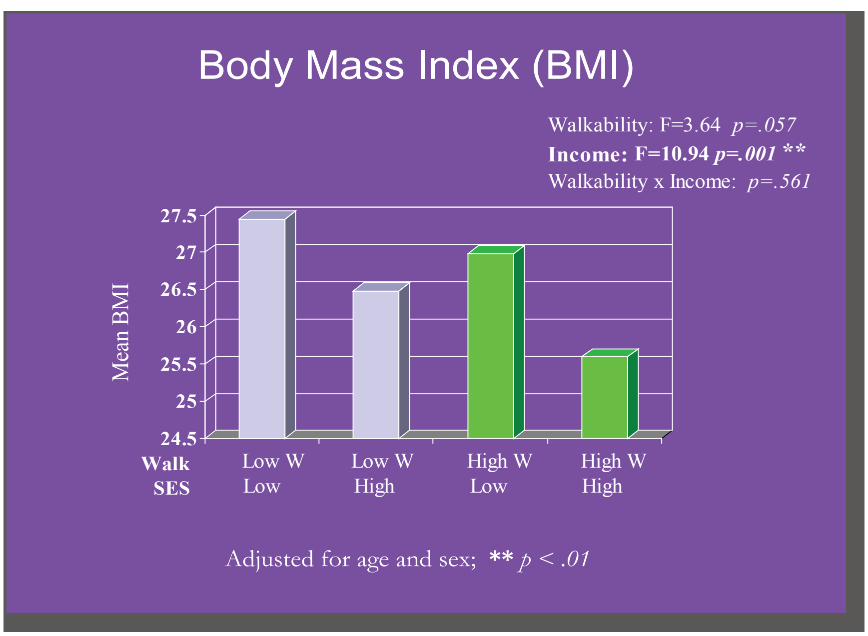


**Figure G: Body Mass Index and Walkability (from Neighborhood Quality of Life Study)**

(Note: W = walkability / SES = income)

When comparing across walkability (high to low), mean BMI decreased from 27.5 to 27.0 for low-income communities and from 26.5 to 25.5 for high-income communities, a result that was significant at the 94.3 percent confidence level. These results suggest walkability is an important predictor of BMI when controlling for income.

## Demonstrating Causality

The research presented in this report relies on cross-sectional data comparing the activities of different people located in different types of neighborhoods. Some would argue we do not know if these results are a function of self-selection: that people who like to walk choose walkable neighborhoods. The reality is that regardless of the reason, LUTAQH and other research shows that people living in walkable places walk more than their counterparts of similar socio-demographic makeup that live in more auto oriented environments. Research quite similar to LUTAQH, conducted in Atlanta, found that one-third of residents in low density, low walkability environments would prefer to live in more walkable places - indicating that both preference and built environment predict behavior.

## The Implications for Resource Allocation

As stated above, a primary objective of LUTAQH is to guide the County's allocation of resources to reduce automobile dependency, increase transportation efficiency, improve air quality, and improve health for King County residents. The study used primarily quantitative forms of analysis to examine the level of transit service, road congestion (relative travel time), and the walkability of the pedestrian environment at the individual and community levels in a variety of neighborhoods.

The past allocation of resources for transit, roads, and pedestrian and bike facilities has influenced the form of our communities. Transportation investment priorities have changed considerably over time. For example, the vintage of a community is reflected in its street network. Using the LUTAQH case studies as examples, White Center is an early 20th Century urban center – a classic "streetcar suburb" – with a gridiron layout of streets and blocks. Kent East Hill was developed more recently with a small network of auto-oriented arterials and many private roads that are part of self-contained developments, often with only one or two outlets to collector or major arterials. These differences are the result of decisions and investments made in past decades: in one case, to build a compact neighborhood centered around transit; in the second, to invest in automobile arterials while allowing somewhat isolated developments with separated uses. The LUTAQH study reveals how these decisions have affected the travel patterns, air pollution, and levels of physical activity observed in differing urban environments.

The results of the LUTAQH study indicate King County should consider allocating its resources to better facilitate reduced auto dependence, increased transit use, and increased ability to walk and bicycle to neighborhood destinations. Whether the goal is to increase transportation efficiency, reduce automobile dependence or improve air quality and health, this study shows that more compact development, a wider variety of land uses close to home and work, and a more connected street network with pedestrian facilities help achieve all of these goals. In order to create these conditions, LUTAQH indicates the County should redirect its resources in the following ways:

1. Transportation investments should place a high priority on the integration of transit and improvements for non-motorized travel, by creating safe facilities and convenient connections for walking, bicycling and access to transit. The County should give higher priority to new transit investments in areas best able to support transit use – based both on current conditions and on tangible commitments by local governments to transit supportive development.

2. Policies and regulations should be evaluated to reduce barriers to building compact, mixed-use developments, and should include incentives for projects that will increase density and diversity in communities countywide.

3. More transportation funding should be allocated to transit and non-motorized improvements. LUTAQH's results suggest that significant savings, in terms of reduced health care costs, could accrue from this action, if done in a concerted fashion (Frank et al 2005b).

## Recommendations

Federal, state, and local laws and policies put King County in a strong position to act on the findings of this report. Federal transportation and air quality laws require the creation of plans that meet air quality requirements and provide transportation choices. The Washington State Growth Management Act established Urban Growth Areas to focus metropolitan growth and to coordinate land use and transportation actions. The Comprehensive Plan in King County supports mixed-use development, non-motorized travel modes and the reduction of single-occupancy vehicle travel; King County's transit plan also focuses on congestion relief and improved mobility. The allocation of resources for improvements and services plays a significant role in the form of our communities and the transportation system. And now, decisions about community form and transportation can be linked to growing public health concerns over obesity, lack of physical activity and respiratory diseases.

LUTAQH also identifies additional actions and policies that can further King County's goals, including activities related to measurement, planning, and implementation, as well as specific initiatives in targeted neighborhoods, described in more detail below. Many of these actions are completely within the County's sphere of influence, because the County has the implementation mechanisms (regulatory and/or fiscal), is the actor, and can monitor its performance towards achieving goals pursuant to a given strategy. Others require cooperation and partnerships with other jurisdictions. The following represent strategies and actions to improve the links between land use, transportation, air quality and health, and are in support of adopted goals within King County's Comprehensive Plan:

## I. Measurement & Education

**a.** **Create performance measures**. The land use, travel behavior, air quality, climate change, physical activity and Body Mass Index (BMI) measures tested in LUTAQH provide a baseline for specific factors that can be integrated into the County's performance monitoring system and tracked over time to determine adherence with adopted policy. Such a "report card" concept is critical to know if things are getting better or worse and where actions need to be taken to improve the quality of life within the region.

**b.** **Establish level of service criteria for all modes of transportation**. What gets measured gets done. The Washington State Growth Management Act requires local governments to adopt level of service standards for arterial streets and transit routes. These standards do not usually include pedestrian trips or calculate the connectedness of a neighborhood. King County should establish level of service measures for walking and bicycling to assess use and adequacy of nonmotorized travel.

**c.** **Educate and inform**. The findings of the LUTAQH study can be used to help the general public understand the benefits of new development patterns and can help draw them into a robust public involvement process. This includes working with other cities, counties, state and regional governments; public interest groups; other disciplines, especially public health agencies; and the private sector, such as property owners, developers and grant foundations.

## II. Policy and Planning

**a.** **Review and change policies and regulations that are a barrier to compact, mixed-use development**. Separation of uses has been a hallmark of land use planning across the United States for decades and now presents a barrier to dynamic mixed-use projects. King County should reassess land use policies and regulations.

**b.** **Create approval processes and incentives for urban developments that**:

- create connected street networks with bicycle and pedestrian facilities,
- expand the trail network,
- increase density using superior design principles, and
- provide a balanced mix of residential, commercial, institutional, and recreational uses.

c. **Develop new criteria for resource allocation in transportation and land use decisions**. This can be accomplished by adding:

- research based land use criteria into the programming process for transportation funding such as the Congestion Mitigation and Air Quality program and other transportation funding sources, and
- health factors in the regional Transportation Improvement Program selection process to recognize the health benefits of projects that enhance walkable communities.

d. **Make land use approvals subject to public health outcomes**. Once it is clear that certain kinds of urban form produce certain types of health impacts, the land use approval process should be used to bring development decisions into alignment with County goals. Incentives should be available for projects meeting the criteria.

e. **Develop Health Impact Assessments**. Major development and transportation actions that impact urban form can be subject to Health Impact Assessment or other formal statements, similar to Environmental Impact Statements. The level of involvement can range from a review/coordination role to a regulatory/approval-denial permitting function. Data collected and models developed by LUTAQH provide the basis for empirical assessment of health-related outcomes of alternative land development and transportation investment proposals[14].

## III. Implementation

a. **Improve street connectivity**. Work with new developments to maximize connections between new projects and surrounding streets. Kent, for example, has developed an ordinance requiring developers to create neighborhood connections for pedestrians and bicyclists, and to install appropriate traffic calming devices.

b. **Give priority to non-motorized travel**. Walking and bicycling should be considered as functional transportation modes on par with the automobile. Designing new streets and roads as "complete streets" that work for all modes can do this. This can also include retrofitting existing streets with walking and biking facilities and/or traffic calming measures to improve travel speed and safety for these modes.

c. **Expand the regional trail network**. Trails offer connections between communities and provide

14 A significant body of evidence exists that links levels of physical activity and obesity with the odds of developing a chronic ailment including cancer, cardio-vascular disease and diabetes (Frumkin et al 2004) Several recent assessments document major increases in health care costs are associated with these types of ailments that may well be most sensitive to the built environment.

opportunities for non-motorized travel to work, shop and recreation.

d. **Increase transit access**. Increase service frequency where increased ridership would result.

e. **Make transit investments that support land use decisions**. Prioritize transit investments in areas where local land use actions support convenient access to transit.

f. **Make pedestrian investments coincident with improved transit service**. Similarly, communities arguing for more transit service must demonstrate how they will improve pedestrian connections. White Center, for instance, needs sidewalks. Without them, people cannot safely or comfortably walk to transit. Communities should work with transit agencies to identify and implement needed pedestrian facilities when transit projects are being planned.

g. **Create a pool of funds for strategic improvements that meet the test of smart development**. Earmark five percent of federal funds, jointly pooled from multiple sources – roads, transit, air quality, and public health – to projects that meet the goals of improved transportation efficiency, air quality, and health. The LUTAQH project demonstrates that real gains come when criteria from multiple disciplines are combined. Projects that can meet the test of multiple successes should have access to funds from multiple sources.

## IV. Specific Initiatives

### a. Partner with the Puget Sound Regional Council (PSRC) on the Vision 2020 Plan Update

The PSRC is in the process of updating its Vision 2020 Plan. As the lead regional planning agency in the Central Puget Sound Region, the PSRC presents an ideal partner for the advancement of the LUTAQH findings. The Vision 2020 Plan represents a collective and commonly held set of values about how the region should grow. The PSRC recently developed a set of "position papers" to inform its board and member jurisdictions on the critical issues the region is facing. One paper focuses on the emerging evidence documenting relationships among land use patterns, transportation investments, and public health. This paper referenced findings from the LUTAQH study documenting links between travel patterns and public health. In addition to public health, LUTAQH includes recommendations for transportation funding and land use regulations based on their impacts on travel choices, regional air quality, and climate change. Findings from these parts of LUTAQH support the Vision 2020 Plan.

Building on the Growth Management Act (GMA) framework in place in the Central Puget Sound Region, King County should work with cities to add new policies to the Countywide Planning Policies to provide guidance to all jurisdictions in the county on how to address public health, air quality, and climate change concerns through their planning and policy level work.

### b. Case studies that point to change

Kent, Redmond, and White Center were the focus of detailed case studies in the LUTAQH study, which included a look at urban form in the communities and a survey asking residents about their travel preferences. Each case study is representative of common neighborhood types in the region. Kent is an auto-oriented suburban district with good proximity between residential and commercial uses, but poor connectivity due to large block structure and surface parking. Redmond is an urban center with a vibrant new commercial center, but limited housing. White Center is an older urban center with a good grid network of streets and a viable commercial core, but needing additional residential density and investments in sidewalks and other pedestrian amenities. LUTAQH found all three communities – and by inference, most neighborhoods throughout the region — would benefit from some basic changes in development patterns. Three approaches are recommended for all communities:

- Increase residential density in commercial areas and promote more mixed use development.
- Expand the regional trail system to connect public spaces with a series of pedestrian and cycling routes within and between neighborhoods within the community and via a series of regional trails where possible among communities.
- Prioritize streetscape improvements, including enhancements to existing and the provision of new sidewalks and crosswalks. Where appropriate install benches, weather protecting transit shelters, lighting standards, trees, and other improvements that enhance the safety and attractiveness of pedestrian connections between activities and with transit.

## Specific Recommendations for Case Study Communities

One of the challenges of this study is to articulate meaningful and appropriate research-based solutions for different types of community environments within King County. The recommendations for each community outlined below flow directly from the research findings. The suggestions should be considered in a community-based planning process. The three case study communities described are representative of hundreds of neighborhoods across King County; the suggestions are presented here to demonstrate the kind of neighborhood-by-neighborhood assessment needed for King County to make the land use and transportation changes that will help it meet its goals. Specific strategies proposed for each community are below.

## Kent/East Hill (auto-oriented district):

- Consider developing a bus station with direct, rapid connections to the transit station in downtown Kent and with efficient connections to other modes.
- Create a system of linear parks along unimproved rights-of-way to create a "green ring" of public open space around Kent East Hill.
- Encourage the gradual redevelopment of shopping malls and big-box retail to mixed use development on smaller blocks.
- Discourage surface parking through design guidelines.
- Permit and encourage housing development above retail space.

In the preference survey of neighborhood residents, the investment most frequently picked as the top choice by Kent respondents was affordable housing, followed by a complete sidewalk system and, thirdly, new or expanded freeways. Affordable housing was again chosen most frequently as a second priority, followed by a network of pedestrian and bicycle pathways and then new or expanded freeways.

## Redmond (urban center):

- Implement Redmond's new Downtown Transportation Plan.
- Develop appropriate local models for high-density urban housing.
- Permit development of non-traditional housing forms, such as live-work spaces.
- Complete an internal bike path network.
- Redevelop an appropriate street hierarchy that emphasizes the nature of some streets as primarily serving local traffic.

In the preference survey, when asked to rank their top three investments, Redmond respondents selected affordable housing most frequently, followed by a new or expanded freeways, more open space, and a pedestrian and bicycle trail system. The most frequent selections for second place were a pedestrian and bicycle trail system, improvements to arterial roads, and affordable housing.

## White Center (older urban center, or "streetcar suburb"):

- Consider rezoning targeted single-family areas to allow infill duplexes and triplexes and increase residential density.
- Complete the sidewalk and street drainage system, including design and development of

natural drainage systems.

- Create an international marketplace/small business incubator building or similar pedestrian destination.
- Develop alternative affordable housing options.
- Establish strong pedestrian links from the new Greenbridge housing to the business district of White Center.
- Consider rezoning underutilized industrial areas to allow more mixed-use development in the central business core.

The surveys conducted as part of the project found that the community supports such changes. The surveys found that the most frequent choices for top priority in community public investment were completing the sidewalk system, developing additional affordable housing, and more parks and open space.

**For more information, visit: www.metrokc.gov/kcdot/tp/ortp/**

# Outline of the Report

The purpose of the LUTAQH report is twofold. First, it describes a research project that identifies relationships between land use and urban form in King County, and patterns of travel behavior, levels of physical activity and obesity, and vehicle emissions and greenhouse gas generated by county residents. Second, the report applies lessons learned from this research to a set of community level case studies and to recommendations for policy intervention and infrastructure investment by King County and its local governments.

**Chapter I** of this report describes the study purpose and its specific goals, and broadly reviews the policy context and issues that have driven the LUTAQH research.

**Chapter II** explains two new areas of emerging concern that are beginning to impact transportation and land use decisions: climate change, and physical activity and health.

**Chapter III** presents the methodology used in the research and details data collection and database development, the creation of land use and urban form variables for analysis purposes, the modelling of regional travel and trip related emissions, and the analysis of physical activity data. Chapter III also provides demographic profiles of the study samples for the databases developed for research conducted at both countywide and community levels.

**Chapter IV** reports the results of the countywide analysis linking land use and urban form variables in King County, and travel outcomes such as walking rates, transit ridership, vehicle miles travelled, vehicle hours travelled, local and greenhouse gas (GHG) trip emissions, and physical activity.

**Chapter V** provides a thorough review of existing conditions in three communities, then draws on the findings of Chapter IV to make recommendations as to how land use, urban form, and transportation programming in these communities can be modified to reduce vehicle usage and emissions, and increase use of alternative travel modes and rates of physical activity, and lower obesity rates. The attitudes of community survey respondents towards such modifications are also presented.

**Chapter VI** describes survey respondent usage of and attitudes towards transportation demand management programs for the trip to work.

**Chapter VII** broadens the recommendations from Chapter V to the county level by discussing ways County strategies for implementing land use, urban form, transportation infrastructure and programming policies can be used to bring about positive changes in travel behavior, air quality and physical health.

## I. Study Context and Purpose, Partners and Funding

We are increasingly aware that there is a connection between how we organize our cities and the ways we get around them, and that our dependence on the automobile for everyday travel has serious implications for public health and quality of life. At the same time, faced with competition among local governments for limited transportation resources, county and municipal governments have begun searching for ways to efficiently allocate transportation funds and make land use decisions that maximize accessibility, public health, and environmental objectives. Specifically, through this study King County is exploring the possibility of creating incentives that reward communities that initiate land development and local transportation actions that support and encourage transit, bicycling and walking, increase efficiency of transportation investment, increase physical activity, and improve air quality. However, the County currently lacks a rigorous method for evaluating the impact of local government land use and transportation actions on travel behavior and related aspects of public health.

While there has been considerable discussion over the impact of local land use actions on traffic congestion and air quality – and, more recently, over their impact on public health -- little work has been conducted to alter the public investment patterns that support low density, single use platting and development. Without altering current approaches to transportation planning and programming on the capital side, and the spatial allocation of transit resources such as service hours, it is unlikely that land use and activity patterns will change. The purpose of LUTAQH is to enable King County to more effectively meet its growth management, transportation, public health air quality, and climate change goals by clarifying the cross-cutting influences of its policy actions in these areas, and to empower King County communities to effectively address land use, travel behavior and air quality issues critical to the future economic and physical health of area residents.

Amongst a wide variety of recommendations, this study outlines some components and actions that would help the County move towards a more performance-based approach to transportation resource allocation. Moving towards a more comprehensive and objective evaluation system for the allocation of countywide transportation investments is clearly a critical component of this project. This first phase of the LUTAQH study makes the case for the development of a set of evidence-based performance criteria to evaluate land use and transit investment impacts on transit ridership, per capita generation of air pollution and green house gases, levels of physical activity from transportation and from recreation, and obesity rates in the central Puget Sound Region. Implementation strategies are under consideration that will enable King County to undertake and to empower its independent municipalities to make land use/transportation decisions necessary to achieve regional goals. In this respect, the County's work is a direct extension of the Puget Sound Regional Council's Vision 2020 and Destination 2030 plans.

The research described in this report was conducted to provide the empirical evidence of land use – travel behavior relationships necessary to develop those performance criteria. This research represents one of the first times that detailed disaggregate land use data has been linked to travel behavior data in order to clearly identify the relationship between land use and transit connectivity on the one hand, and travel behavior, physical activity and air quality on the other. By sponsoring this research in order to better inform its transportation, land use, air quality and public health planning processes, King County is creating a national model for the integration of research, policy development and practice, and is among the first jurisdictions in the nation to use its land use regulatory authority to influence travel and health related outcomes. Figure 1 conveys the model guiding this research, whereby land use and transportation investment decisions shape physical activity patterns, influencing both quality of life and public health of area residents.


**Figure 1: Built Environment, Activity Patterns, Health**

Source: Health and Community Design:

The Impacts of the Built Environment on Physical Activity

(Frank, Engelke, and Schmid, 2003)

A central focus of the LUTAQH effort is application of research to practice. This study represents a novel approach taken by a local government to conduct applied policy research in order to inform its transportation investments and land use decisions. King County is uniquely positioned to impact both of these arenas that shape the built environment, given its role as the regional transit provider and the coordination through the countywide planning policies provided through state growth management legislation (see below). Figure 2 displays the conceptual relationship between research and practice that has guided this project. Partners in the LUTAQH research include the King County Departments of Transportation and Development and Environmental Services, the Puget Sound Regional Council, the Cities of Seattle, Kent and Redmond. The Federal Transit Administration and King County provided funding to address linkages between land use, transportation, and air quality. Additional funding was provided directly to Lawrence Frank and Co., Inc. by the Centers for Disease Control and Prevention and the National Institutes of Health to address the public health aspects of growth and development within King County.

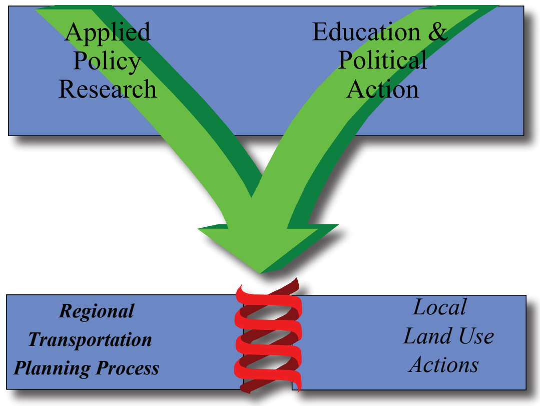


**Figure 2: Research and Practice Partners**

## II. Goals and Products of the Research

The four primary goals to the research described in this report are as follows:

1. Provide empirical evidence of land use – travel behavior relationships across socio-economic groups in King County, with special emphasis on the relationships between land use patterns/ urban form, transit ridership, non-motorized mode choice, household VMT and emissions, and physical activity.

2. Based on interpretation of identified relationships, provide policy guidance to government on ways in which land use policy and transit service allocation strategies can be used to promote use of transit and non-motorized modes, improve accessibility and equity, reduce congestion, reduce emissions, manage growth and improve public health.

3. Identify potential measures (regulations, incentives, etc.) which local governments can adopt to implement such land use and transit allocation strategies.

4. Identify priority areas for the implementation of such strategies.

These goals encompass the purpose of this first phase of the LUTAQH study. This effort uniquely represents the integration of disparate disciplines. Moreover, it reflects the ideal that research can and should be informed from practice, in the sense that practitioners can engage directly in research, and should be better consumers of research to inform their decisions.

In a time of increasingly scarce resources, it is imperative that efforts be made to maximize the longer-term benefits of transportation investments. It is incumbent upon elected officials to provide leadership that ensures the urbanization process (both in the development of new communities and the redevelopment of existing ones) maximizes the general public's quality of life. The research effort described here engages and integrates a variety of substantive topics surrounding growth and development and seeks answers about how to best manage precious resources. The leadership and vision provided for this study by King County and its stakeholders represents a groundbreaking effort to effectively move towards a more sustainable future. Clearly, the Seattle region leads the nation in its efforts to initiate growth management legislation, and demonstrates the degree of consciousness required to implement a set of aggressive strategies to offset increasing greenhouse gas emissions on a regional scale. If any major metropolitan area of the U.S. can turn around the seemingly endless tide towards increased auto dependence, it is the Central Puget Sound. It is the ultimate vision of this report to help make that happen.

# Chapter I: Policy Framework

## I. Introduction

This chapter reviews the relationship between federal, state, regional and county land use, transportation, and air quality policies, with a brief discussion of issues surrounding the implementation of these policies at the local level. This summary will provide an understanding of the policy framework surrounding these issues, which drive the LUTAQH research.

## II. Air Quality—The Clean Air Act Amendments of 1990 (CAAA) and the Clean Air Washington Act

The 1990 Amendments to the Clean Air Act (CAAA) establish stringent national air quality standards and create requirements for their timely attainment. Title I of the CAAA establishes criteria for attaining and maintaining the National Ambient Air Quality Standards (NAAQS). These are federal standards developed by the EPA, which set allowable concentrations and exposure limits for various pollutants (USDOT, 1992). EPA has released nonattainment area designations for the following pollutants: ozone ($O_3$), carbon monoxide (CO), and particulate matter (PM-10 micron). Depending on the severity of the air quality problem, officials in each nonattainment area must take specific actions within a set time frame to reduce emissions. The actions become more numerous and stringent as the air quality problems worsen. These strategies are contained in the State Implementation Plan (SIP). In Washington State, the Seattle-Tacoma area has been designated by the EPA as a maintenance area for CO, PM and $O_3$ for some time (PSRC, 2001).[1]

In Washington, the provisions of the CAAA are implemented through the Clean Air Washington Act and administered by the Washington State Department of Ecology (WSDOE). WSDOE in turn delegates certain responsibilities to regional air authorities such as the Puget Sound Clean Air Agency (PSCAA). The primary tool the CAAA recommends to achieve clean air in urban areas is to change travel behavior, in particular to reduce total vehicle miles travelled (VMT). The legislation places significant restrictions on vehicle emissions in recognition of the fact that the majority of all urban pollutants come from single occupant vehicle travel (PSRC, 1992).

In addition to administering the Clean Air Act and the Clean Air Washington Act, the Department

1 It should also be noted that the standards for particulate matter have changed as a result of TEA-21. Given increased understanding of the health effects of fine particulate matter, the Environmental Protection Agency issued revised standards for particulate matter under the Clean Air Act in 1997 to focus attention on PM2.5 instead of PM10 in specified areas. Furthermore, TEA-21 calls for full Federal funding of a monitoring network for the PM2.5 standard. The EPA is to designate areas with regard to their attainment of the PM 2.5 standard no later than December 31, 2005 (TEA-21, 2002).

of Ecology is responsible for preparing the State Implementation Plan (SIP) mandated by CAAA. The SIP contains procedures to monitor, control, maintain, and enforce National Ambient Air Quality Standards. The SIP may contain Transportation Control Measures (TCMs) that seek to alter travel behavior and reduce motor vehicle emissions. The SIP also contains transportation conformity requirements, and transportation plans and programs in nonattainment areas must meet the "purpose" of the SIP (USDOT, 1992). Transportation plans and programs cannot create new NAAQS violations, increase the frequency or severity of existing NAAQS violations, or delay attainment of the NAAQS. Conformity determinations are to be made no less than every three years (USDOT, 1992).

## A. Linkages between CAAA and TEA-21

Figure 3 describes the well known interaction between TEA-21 and CAAA. The provisions of these policies overlap where nonattainment occurs; for example, failure to implement the SIP or conform to other provisions of the CAAA can result in the withholding of federal highway funds available through TEA-21. This sanction was first reinforced by provisions in the Intermodal Surface Transportation Efficiency Act (USDOT, 1992). The Central Puget Sound Region is in attainment for all criteria pollutants at present, including under the 8 hour standard for ozone. However, up until the late 1990s the region was in non-attainment. More recently, the region experienced 2 out of 3 allowable ozone violations; one more violation would have resulted in being re-designated as a non-attainment area. Given projected increases in VMT and increasingly warmer summers expected in the coming years, violations are likely and will potentially threaten the region's access to federal transportation funding.

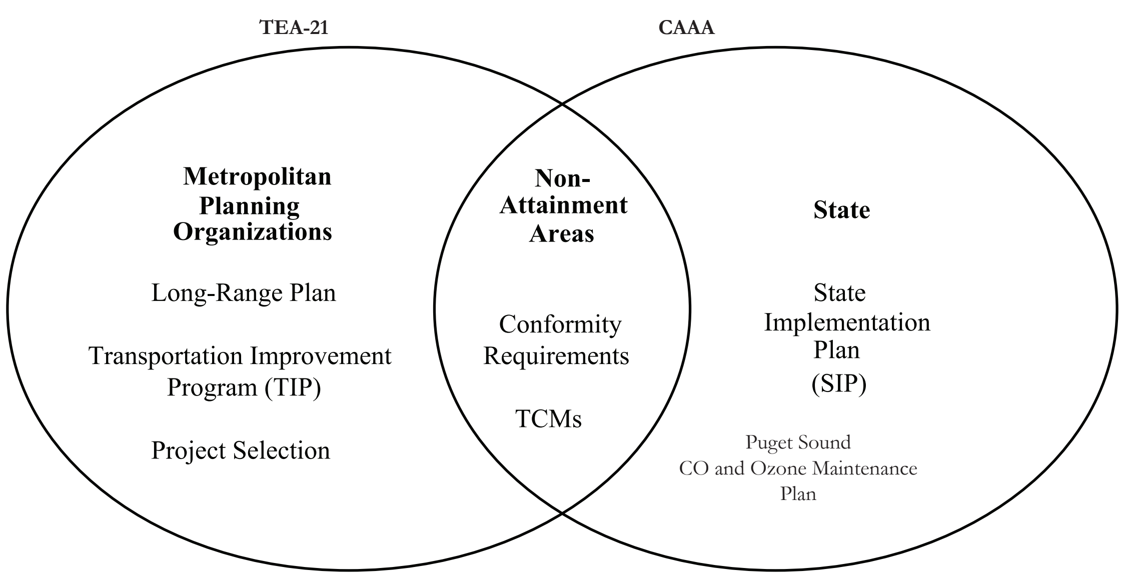


**Figure 3: Interactions between TEA-21 and CAAA**

(Source: Washington ISTEA Steering Committee, 1992)

Under the provisions of TEA-21, state and regional transportation improvement programs (TIPs) and long-range transportation plans must help to implement the SIP. The TIP is composed of projects drawn from conforming local and regional transportation plans. Specifically, the projects and programs contained in the TIP must contribute to the reduction of motor vehicle emissions. Under TEA-21, only transportation projects that are federally funded or approved must meet the conformity requirements, but all projects of regional significance must be included in the TIP and modeled for their conformity to air quality goals (USDOT, 1992). At present, the Central Puget Sound is designated as a Maintenance Planning Environment. However, the prospect of future non-attainment brings the spectre of further CAAA requirements:

- Transportation plans and programs must provide for expeditious implementation of the TCMs consistent with the schedule in the SIP;
- Transportation plans and programs must contribute to annual emissions reductions;
- Transportation projects and programs must come from a conforming plan or program; and
- Emissions expected from the plan or program must be consistent with the scheduled emissions budget in the SIP.

The Washington State Growth Management Act (GMA – described in more detail below) further strengthens the relationship between the State Implementation Plan or Maintenance Plan and state, regional, and local transportation plans. While TEA-21 only requires that federally funded or approved projects meet air quality standards, Washington's GMA specifies that all projects of regional significance, regardless of funding sources, are subject to conformity. Furthermore, the GMA calls on local communities to "rethink the traditional approach to transportation planning" (Washington State OCD, 2002); conformity requirements specify that all transportation plans must be consistent with each other and with related land use plans. As a result, any air quality provisions required in state-level transportation plans must also be reflected at the regional and local levels.

## B. Air Quality Policies in King County Comprehensive Plan

While acknowledging that the Puget Sound Clean Air Authority takes the lead role in managing regional air quality, the King County Comprehensive Plan recognizes that King County must take a more active role in protecting and improving regional air quality, especially as it is influenced by land use and transportation policy and planning decisions at the county level. In reflection of the requirements of Washington's Clean Air Conformity Act, the Comprehensive Plan states that "Air quality impacts of proposed land use actions shall be assessed when developing countywide, subarea, and local plans and transportation strategies" (King County 2000). Specifically, the plan includes the following key policies:

- Working with other levels of government to develop transportation control measures and programs as needed; and
- Considering county-level strategies for the reduction of criteria air contaminants, including transportation demand management measures, promotion of alternatives to the SOV, and encouragement of mixed use development (King County 2000).

# III. Transportation/Congestion/Mobility/Accessibility

## A. Federal Level

The Intermodal Surface Transportation Efficiency Act (ISTEA 1991) introduced, and the Transportation Equity Act for the Twenty-First Century (TEA-21 1998) continued a number of provisions designed to help meet the transportation emissions reduction goals in the federal Clean Air Act. The recent reauthorization of this act in 2005 continues most, if not all, of these programs.

### 1. Congestion Mitigation and Air Quality Improvement Program

Through the Congestion Mitigation and Air Quality Improvement Program (CMAQ), TEA-21 provides a categorical funding source for implementing the transportation emissions control portions of the SIPs for attainment of air quality goals required by the Clean Air Act. Strategies in the SIP for reducing transportation-related emissions receive high priority for funding under CMAQ. Projects eligible for funding include transit, transportation demand management programs, ride sharing, and bicycle and pedestrian facilities (Washington ISTEA, 1992). In TEA-21, eligible activities were expanded to include transit improvements, travel demand management strategies, traffic flow improvements, and public fleet conversions to cleaner fuels, among others. The current reauthorization of TEA-21 will likely sustain this linkage between transportation funding and clean air policy, and add additional programs such as funding to support safe routes to school for children and complete streets that accommodate a variety of transportation modes. Under TEA-21, allocations from the Federal Highway Aid Trust Fund can be transferred to fund CMAQ projects. Funds are distributed to states based on a formula that considers population by county and the severity of air quality problems within nonattainment or maintenance areas (TEA-21, 1998). Projects in nonattainment areas for ozone or carbon monoxide will not be funded under CMAQ unless the project or program is likely to contribute to the attainment of a national ambient air quality standard, or if the project is included in a State Implementation Program approved pursuant to the Clean Air Act; and the project will have air quality benefits or is likely to contribute to the attainment of a national air quality standard, through reductions in vehicle miles traveled or fuel consumption, or through other factors.

Furthermore, in nonattainment areas no CMAQ funds may be provided for a project that will result in the construction of new SOV capacity, unless the project consists of an HOV facility available to single occupant vehicles only after peak travel times (ISTEA, 1991). Under TEA-21 the areas eligible for funding through CMAQ have been expanded to include PM-10 nonattainment and maintenance areas, as well as areas designated as nonattainment under the 1997 revised air quality standards. CMAQ funding has also been made available for experimental pilot projects such as studies like SMARTRAQ in Atlanta (see www.act-trans.ubc.ca) and other efforts to investigate longer-term air quality improvement strategies. One of the possible outcomes of the study will be the application of LUTAQH findings to the CMAQ project selection process.

TEA-21 includes several programs, implementation mechanisms, and planning tools which attempt to tie transportation decisions to air quality considerations. TEA-21 funds can be used for the implementation of transportation control measures (TCMs) as well as transit, carpool, and vanpool projects in metropolitan areas in non-attainment for ozone or carbon monoxide. TEA-21 also requires co-ordination with Clean Air Act Agencies. The metropolitan planning organization is to "coordinate the development of a long-range transportation plan with the process for development of the transportation control measures in the State Implementation Plan (SIP)" (Washington ISTEA, 1992). In addition, state and local transportation plans must be modeled for air quality conformity and determined to be consistent with the SIP, and federal transportation funds can be withheld from states or regions that fail to comply with these mandates (ISTEA, 1991).

## 2. Federal Transportation Policy and Transit

According to the original ISTEA legislation, "significant transit improvements are necessary to achieve national goals for improved air quality, energy conservation, international competitiveness, and mobility for elderly persons, persons with disabilities, and economically disadvantaged persons in urban and rural areas of the country." Not much has changed since 1991 when that was written. To ensure that transit is integrated into state and regional transportation planning efforts, ISTEA requires that "methods to expand and enhance transit services" be included in state and regional transportation plans (ISTEA, 1991). To further encourage transit as a viable alternative to automobile travel, ISTEA theoretically changed federal funding for transit projects by increasing the possible share of federal funds available for transit capital projects and operating expenses, and setting the federal share for transit projects at eighty percent--the same as for highways. ISTEA created "flexible funding" which gave local governments the opportunity to use roadway dollars for transit and visa versa, although no transit funds can be transferred until a very specific set of requirements are met (Washington ISTEA, 1992). TEA-21 has continued this more flexible approach to transit funding.

In addition, TEA-21 also redefines capital projects to include facilities that incorporate community services such as day-care and health care (TEA-21, 1998(a)). Supporting development of neighborhood serving land uses can help to reduce trips out of communities, and improves accessibility for those without cars. More recently, the Jobs Access/Reverse Commute (JARC) program was initiated through federal transportation funding via TEA-21. JARC has the potential to encourage transportation funding that is more sensitive to benefits and burdens to specific populations that stem from income disparity. This program provides competitive grants to communities and non-profit organizations to develop transportation services to connect low income and welfare recipients with employment and support services (TEA-21, 1998(b)).

### 3. Implementation

TEA-21 is implemented through state and regional long-range policy plans and short-range implementation programs. The long-range plan is a 20-year forecast plan that must consider a wide range of social, environmental, energy, and economic factors in determining overall state and regional goals. In Washington, the long-range state transportation plan is known as the State Transportation Policy Plan (STPP). The Metropolitan Transportation Plan (MTP) is the official long-range plan operating at the regional level. These state and regional long-range plans are implemented through annually updated short-term 3 year Transportation Improvement Programs (TIPs). In a sense, the MTP is the *menu* and the TIP is the *meal*. Whereas the MTP spells out the general direction and sets of projects worthy of consideration, or what's available on the *menu*, the shorter term TIP is what is obligated, or ordered as the *meal*. One of the primary developments currently underway at the state level is the update to the State Transportation Policy Plan to include a health and a carbon dioxide ($CO_2$) component. Depending on how these sections are written, they have the potential to provide the necessary backdrop for the region to become more focused on some of the themes of the LUTAQH study.

The state TIP or STIP is a compilation of regional TIPs. At the regional level, the TIP must establish priorities for all surface transportation projects for all jurisdictions in the region in order to be eligible for federal funding. In addition, under Washington State transportation planning conformity requirements, all state and locally funded projects must be evaluated for consistency with the relevant Metropolitan Transportation Plan (MTP) and must be included in the TIP in order to be modelled for air quality conformity (PSRC, 2001). This process ensures that TIPs consider the potential air quality impacts of all changes to the transportation system.

## B. Regional Level

### 1. Destination 2030

Destination 2030, the Puget Sound Regional Council's Metropolitan Transportation Plan (MTP), lays out a program to address transportation problems by investing in more roads, providing more transit service, improving traffic management, and improving linkages between land use and transportation planning. The plan identifies over 2,200 specific projects that will improve roads, transit and ferry service (PSRC, 2001). Destination 2030 is action oriented, and focuses on implementation and monitoring of regional projects such as transportation enhancements, congestion management, intelligent transportation systems, growth strategies, transit oriented development, and bicycle and pedestrian programs, to name a few.

One element of Destination 2030 of special importance to this project is the goal of specifically defining the linkage between land use and transportation planning and outcomes, as addressed in Vision 2020. This aspect of Destination 2030 is "focused on preserving and developing complete communities, redeveloping urban transportation corridors, and directing employment and housing growth into locations and patterns that make it easier to walk, bike, and use transit. Additional urban design guidance, as well as descriptions of different types of development strategies and financial incentives, will reinforce the critical link between land use and transportation planning." (PSRC, 2002)

## 2. Transportation Policies in the King County Comprehensive Plan

King County's Comprehensive Plan guides County transportation and transit planning, though the overall direction taken by transportation policy in the Comprehensive Plan is derived from the PSRC's Metropolitan Transportation Plan. In addition, the concurrency requirements put forth in Washington's GMA also influence the Comprehensive Plan's direction. Concurrency requirements state that development cannot be approved unless improvements are developed concurrently (within six years) to mitigate transportation impacts resulting from that development, in order to maintain levels of service on the transportation network at standards set in the Comprehensive Plan. The high costs and negative side effects associated with constructing additional road network capacity to maintain the pre-established network levels of service (through concurrency) has resulted in some shift in local plan policies and guidance. Primarily, policies have emerged in Comprehensive Plans that encourage land use and development strategies that result in the least increase in vehicle traffic on the road network (King County, 2000).

Policies included in the Comprehensive Plan which support the concurrency requirements include:

- Support for Transportation Demand Management (TDM) strategies which maximize the efficient use of the existing transportation network by reducing SOV travel and encouraging use of alternatives;
- Directing future development to the designated urban growth area (UGA), so that existing transportation infrastructure is used most efficiently, and transit service can be provided

effectively;

- Support for mixed use developments within the UGA, in order to reduce the need for longer trips on the regional road network;
- Developing, along with local jurisdictions, mode split goals to established employment centers, and strategies to reach those goals (King County, 2000).

The King County Comprehensive Plan is also supportive of bicycling and walking for transportation. Specifically, it includes policies which promote the use of these modes in order to expand areas effectively served by transit and increase personal mobility in a broader range of land use types. The plan calls for incorporation of enhancements to these modes whenever transportation improvements are considered.

Finally, the Comprehensive Plan also provides policy guidance for the integration of transit system development and land use planning, in accordance with Washington's GMA requirement to integrate transit planning with the Comprehensive Plan. The Comprehensive Plan calls for development of land use regulations which promote transit use through increased density, affordable housing, and mixing of uses, especially along transit corridors and near transit stations (King County, 2000). Countywide transit planning policy is more thoroughly developed in the County's Transit Development Plan.

### 3. King County Six-Year Transit Development Plan

King County's current six-year transit plan (2002-2007) is focused on the goals of congestion relief and improved mobility. The Transit Plan's mobility goals, which are of most interest to this study, include implementing transit system improvements in those areas where land use is most supportive of efficient transit service provision and most likely to attract high ridership – primarily within King County's UGA – and encouraging new developments that are transit-oriented (King County, 2002).

Specifically, the plan seeks to work with "jurisdictions that aggressively implement local land use plans, growth management strategies, and regulations to facilitate development that is supportive of transit service." It focuses enhanced service provision in those urban centers that achieve their growth targets and "encourage higher density development and pedestrian activity through adopted regulations and policies that advance transit-supportive development, promote mixed-uses, establish minimum densities, and reduce parking requirements" (King County, 2002).

# IV. Land Use/Urban Quality of Life

## A. The Washington State Growth Management Act (GMA)

In June 1990, the Washington State Legislature passed Engrossed Substitute House Bill 2929 -- the Growth Management Act (GMA). The GMA is a framework for "managing growth in a coordinated and comprehensive manner" and better coordinating land use and transportation planning in Washington State. Under GMA, local comprehensive plans are required for all counties (and cities within those counties) that have a population of over 50,000 people or growth rates of more than 20 percent over the previous 10 years (GMA, 1990). These plans must contain transportation and land use elements. Transportation concurrency requirements directly link new growth to transportation plans and financing. In 1991, the GMA was amended to further define requirements and to establish a framework for co-ordination among local governments through countywide and multi-county planning policies (Frank, 1994).

The GMA also requires counties to designate urban growth areas of sufficient size and density to accommodate the urban growth projected to occur in the County for the succeeding 20-year period. The Act is intended to reduce sprawl and direct development to urban areas where public facilities and services exist or can be efficiently provided. By encouraging more compact development, the GMA seeks to "preserve rural lands and natural resources." Countywide and multi-county policies are required to implement these provisions (GMA, 1990).

While GMA mentions air quality as a primary consideration for local plans and regulations, it posits no specific recommendations as to how local jurisdictions should protect or improve air quality. Clearly, however, some of the transportation policies mentioned later in the act are meant to improve air quality and traffic congestion.

Under GMA, local transportation plans are to be based upon projected land use patterns and the projected travel demand generated by those land use patterns. One of the goals of GMA is to "encourage efficient multimodal transportation systems that are based on regional priorities and coordinated with the county and city comprehensive plans" (GMA, 1990). The transportation programs and policies outlined in GMA seek to maintain an efficient level of service and indirectly benefit air quality. The GMA requires cities and counties to adopt demand management strategies that may "include increased public transportation service, ride sharing programs, demand management, and other transportation system management strategies" (PSRC, 1995). The Growth Management Act also requires that countywide policies be adopted to include transit oriented development and financial programs consistent with its comprehensive plan and the State Transportation Policy Plan (PSRC, 1995).

One of the most important aspects of the Growth Management Act is the mechanism it creates for implementation of policies and programs. The GMA requires consistency between federal, state, regional, and local plans. This consistency requirement extends to state and local agencies that operate in jurisdictions required to plan under the GMA. Plans must also be internally consistent, which means that transportation plans must support prescribed land use plans and be recognized within the capital facilities element of the local government's comprehensive plan. Local comprehensive plans and development regulations are also required to comply with the provisions of GMA and with each other. However, in many cases there is a profound gap or lack of consistency between what is recommended in a local government's comprehensive planning policies, and what is effectively implemented through their development regulations.

GMA further matches local development to land use and transportation plans through concurrency. Transportation concurrency is the requirement to mitigate the impacts of development to a pre-established level of service (LOS) standard. According to GMA, "public facilities and services necessary to support development shall be adequate to serve the development at the time the development is available for occupancy and use without decreasing current service levels below locally established minimum standards" (GMA, 1990). This has been interpreted to mean that improvements must be in place within six years of occupancy or permitting. Timely improvements to maintain LOS could benefit air quality by relieving congestion.

The land use and capital facilities elements of local plans noted above are required under GMA, and must be co-ordinated and consistent. In keeping with federal transportation policy, the capital facilities element must be financially constrained. In other words, improvements cannot be included in the six-year capital facilities plan unless funding is available for the improvement during the six-year period. If funding is inadequate, then the land use element must be reassessed "to ensure that the land use element, capital facilities plan element, and financing plan within the capital facilities plan element are coordinated and consistent" (GMA, 1990). This system of consistency between plans ensures that policies from the state and regional level are implemented through comprehensive plans and development regulations at the local level. Therefore, any policies regarding air quality, transportation, or land use adopted as part of GMA should be incorporated into local practice.

## B. Vision 2020

Vision 2020 is a long-range growth management, economic development, and transportation investment guide for the Central Puget Sound Region. This plan identifies ways in which sound investments can be made in urban and rural areas to improve quality of life. Vision 2020 calls for urban growth areas with development focused in compact walkable communities with a good mix of housing and employment, so that services can be provided efficiently. By encouraging infilling and urban densification, Vision 2020 also aims to conserve farmland, forests and other natural resources. The plan strives to preserve rural areas by supporting uses consistent with rural character, such as farming, forestry, and low-density housing.

Vision 2020 is composed of eight interlinked and overlapping policy areas, which together provide comprehensive coverage of planning goals:

- Urban Growth Areas
- Contiguous and Orderly Development
- Regional Capital Facilities
- Housing
- Rural Areas
- Open Space, Resource Protection, and Critical Areas
- Economics
- Transportation

As stated by the PSRC,

> *"VISION 2020 provides a regional framework for achieving these goals that builds upon and supports local, countywide, regional and state planning efforts. Countywide planning policies in each of the counties supply the local framework and provide additional detail for county and city comprehensive plans. The policies in VISION 2020 reflect broad directions agreed to by member jurisdictions and agencies, and are not meant to necessarily convey regional responsibility for implementation. Many of the policies reflect and will be implemented through local comprehensive plans, and transit agency and state transportation plans and programs, as well as regional efforts" (PSRC, 2002).*

Regional elected officials have formally adopted this plan, indicating their commitment to its importance and their awareness that counties must work together to solve regional issues. Implementation of Vision 2020 occurs through regional action, local comprehensive plans and development regulations, transit agencies, and state transportation plans. The Puget Sound Regional Council has three primary ways to implement Vision 2020. These include policy and plan review, development of the regional TIP, and monitoring. Policy and plan review are GMA requirements. The TIP is required by TEA-21 and must be consistent with the Metropolitan Transportation Plan and the state air quality SIP. Monitoring of progress is required by both TEA-21 and CAAA, and provides information on the specific steps that the region, cities, counties, and agencies are taking to implement transportation, land use, and environmental policies.

Vision 2020 creates a framework for local planning based on concentrated growth areas connected by an efficient transportation system. Together, Vision 2020 and the Metropolitan Transportation Plan (MTP) are designed to address the region's transportation problems in compliance with federal and state transportation, air quality, and growth management legislation. Under Washington's GMA, the PSRC must certify that transportation components of comprehensive plans are in conformity with Destination 2030. A monitoring system has been put into place to review project goals and outcomes to ensure this conformity.

## C. Land Use Policies in the King County Comprehensive Plan

King County developed its first Comprehensive Land Use Plan under the Washington State GMA in 1994. The plan underwent a major review in 2000, and recommended updates resulting from the 2004 review are currently before the King County Council. The County's comprehensive plan is designed to meet the goals specified in the state GMA, as well as county and community goals and aspirations laid out in the 1992 Countywide Planning Process. The Comprehensive Plan provides a framework for decision making about land use in unincorporated areas of the County, and provides incorporated communities within the County with a coherent and comprehensive summary of the County's position on growth management issues (King County 2000).

The plan includes a designated urban growth area (UGA) focused in and around existing urban centers in the County, which will absorb most future growth in order to limit sprawl and maximize the efficiency of use of public infrastructure resources. The plan includes the following key polices regarding the development of urban centers:

- Minimum housing densities in new developments, and increases in density in existing developments only where existing public services, including transit services, are adequate.
- Use of density incentives to encourage developers to provide, among other things, "innovative affordable housing, significant open space, trails and parks, and [locations] close to transit."
- Mixing of high density residential development with retail and service uses, in designated Community and Neighborhood Business Centers, Activity Centers, and Commercial Areas.
- Innovative, high quality infill development that increases the range of housing types and prices available and optimizes use of designated urban lands through higher density development.
- The direction of new jobs and housing to existing urban centers in the UGA through the use of growth targets.
- The development of Community Business Centers that are accessible by public transit, pedestrians and cyclists.

The plan includes the following policies with regard to housing:

- Support for affordable housing by enabling development of innovative housing types and preservation of existing affordable housing.
- Ensure a balance of jobs and housing in County communities to reduce demand on the regional transportation system (King County 2000).

## V. Summary of Air Quality, Transportation and Land Use Policy Interactions

Over the past fifteen years several new pieces of legislation have been enacted at the federal, state, and regional levels to regulate air quality, transportation, and land use, resulting in a comprehensive framework for action on these issues. The Clean Air Act Amendments of 1990 (CAAA) establish transportation control measures (TCMs) which are included in State Implementation Plans (SIP) for air quality attainment. ISTEA and TEA-21 require that TCMs be included in long-range transportation plans and Transportation Improvement Programs (TIPs). Transportation plans utilizing federal funds must be modeled for air quality conformity pursuant to the CAAA and other federal regulations. Washington State regulations takes conformity a step further by requiring air quality modeling for all transportation plans, regardless of funding. Washington's Growth Management Act (GMA) requires that the transportation elements of county and local plans be consistent with land use elements. The concurrency requirements in the GMA also require that transportation related impacts of development be mitigated. The various interrelationships of these policies can be seen in Figure 4 below.

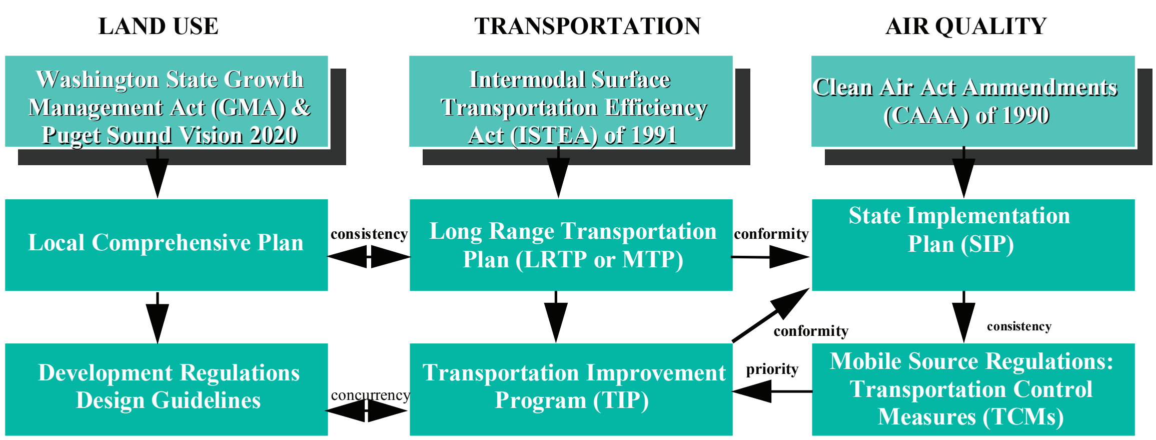


**Figure 4: Interrelationship of Federal, State, and Regional Policies**

Source: WSDOE, Frank and Minton 1996

State, regional and county policies build upon CAAA, ISTEA, and GMA. Washington's State Environmental Policy Act evaluates air quality, transportation, and land use impacts at the project level. Adverse impacts can be mitigated by modifying proposals before they are implemented. The Washington State Commute Trip Reduction Act seeks to improve air quality through transportation demand management (TDM). Recommended TDM strategies include transit supportive land use development, specifically increased density and improved land use mix around transit facilities. The State Transportation Policy Plan also encourages transit use and calls for an integration of transportation, environmental, and land use concerns in the formulation of transportation plans and programs. PSRC's Vision 2020 builds upon the policies described above to develop an integrated regional land use and transportation program. Its goals include the creation of transit oriented developments in order to improve air quality and reduce congestion, as well as increased density, land use mix, and jobs-housing balance. Finally, King County's Transit Plan seeks to allocate additional transit service first and foremost in locations where local governments aggressively pursue transit-supportive land use policies

Although these policies make an explicit link between land use, travel behavior and air quality and acknowledge the need to link these issues in planning processes, in some areas they fall short in fully implementing this integration at the local level:

- While CAAA clearly defines the requirement for conformity between the State Implementation Plan, transportation control measures, and transportation plans, it does not specify the jurisdictional authority of air quality, transportation and land use planning agencies. Air quality is perceived by most local jurisdictions to be a regional problem; as a result, air quality considerations are rarely a priority in local plans, although King County's Comprehensive Plan does acknowledge that County-level action is needed to maintain and improve air quality. In addition, because of the jurisdictional ambiguity of CAAA, regional air quality agencies have been hesitant to mandate policies affecting local transportation investments and land use decisions. Instead, the agencies operate in an advisory role; they offer suggestions, but are unable to exert any real power or demand change. If local land use and transportation policies are to contribute to the attainment of regional air quality, these relationships must be clarified.

- CAAA places major emphasis on changing travel behavior – in particular, reducing vehicle miles traveled – to achieve clean air in urban areas (PSRC, 1992). The legislation also places significant emphasis on reducing vehicle emissions, in recognition of the fact that the majority of all urban pollutants come from single occupant vehicle travel. Currently, transportation control measures (TCMs) that focus on changing travel behavior are among the most popular policy approaches to reducing mobile source emissions. However, as vehicle miles traveled (VMT) and vehicle hours of travel (VHT) continue to increase due to growth in metropolitan areas, traditional TCMs which focus on travel behavior to the exclusion of land use considerations will prove less effective in meeting air quality standards. Structural measures with long term influence, such as the alteration of land use patterns, will be needed to meaningfully alter travel behavior and improve air quality.

- The assessment of the conformity of transportation plans with air quality requirements currently required by CAAA, ISTEA, and GMA could be improved. Currently, all individual transportation projects included in a particular plan are modeled collectively. This means that individual projects which cause concentrated or localized problems known as "hot spots" may be included in a TIP or other transportation plan because their regional impact is offset by other projects in the plan.[2] Currently, there is no mechanism through which to weigh the localized costs of "hot spot" emissions problems against the regional air quality benefits that may be derived from concentrated development. Likewise, there is no process with which to integrate the findings from local project level analyses with regional transportation investment decisions such as TIPs. Better integrating local and regional levels of decision making would assist the evaluation of regional transportation and air quality costs and benefits associated with development proposals which seek to capitalize on high levels of land use mix, density, and existing transportation infrastructure. Such a development would help both to foster use of alternatives to the automobile, and conformity with federal air quality requirements (Frank, 1996).

- To meet the requirements of CAAA, transportation and air quality officials need to establish new partnerships and cooperative approaches in order to identify innovative solutions to transportation and air quality problems. State and local planning and air quality officials will need to coordinate early in the development of land use and transportation plans to ensure that air quality concerns are adequately considered.

- Washington's GMA establishes a comprehensive system of concurrency and consistency requirements. However, as implemented, only transportation projects are required to be consistent and concurrent with land use. GMA could be amended to include conformity with air quality and other environmental policies so that local land use and transportation plans would have to complement these policies.

- The State Environmental Policy Act is the only legislation reviewed in this report that addresses air quality at the project level. For this reason, it is essential that the SEPA review process be sound. Currently, mobile source emissions can be declared "non-significant" without any testing or evaluation. At a minimum, the SEPA review process should explore emissions derived from a proposal's potential trip generation.[3]

- The State Transportation Policy Plan is general in its assertion that land use, transportation, and environmental considerations should be integrated. To effectively shape travel behaviors

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2 "Hot Spots" are identified through the project level environmental assessment process required by SEPA.

3 The SEPA environmental review process is being integrated with the Growth Management Act review process. This may result in a more comprehensive and detailed project review process; unfortunately, the potential also exists for a weaker environmental review checklist than exists currently.

that will significantly impact air quality, the integration of policies must be made more specific, and the land use patterns needed to bring about those changes in behavior must be specified.

- Vision 2020 and the Commute Trip Reduction Act have been vigorously incorporated into local comprehensive plans. These policies have met with varying degrees of success in actual implementation; while the principles and concepts underlying the policies are accepted as sound, the market has been slow to embrace measures such as ride-sharing and increased residential density.

Local plans and development regulations incorporate new policy initiatives that are mandated from a higher level. For example, extensive changes in local plans were required to incorporate the provisions of the GMA and Vision 2020, as well as higher-level air quality regulations. Nonetheless, air quality is generally considered to be a regional rather than local problem, and is not factored into local land use planning, although King County has included policy guidance in its Comprehensive Plan that supports urban growth boundaries and mixed use developments as methods of reducing transportation-related emissions. As the research in this report shows, land use decisions made at the local level have a direct effect on travel behavior and air quality. The linkage between land use, travel behavior and air quality needs to be made explicit in local planning, and there needs to be better integration of local and regional planning and implementation in these areas. Further information on federal, state, and regional policies in these areas and their implementation by local governments can be found in *Land Use Effects on Travel Demand and Air Quality in the Central Puget Sound Region, Report I: Land Use Planning for Transportation and Air Quality Under Growth Management* (Frank and Minton, 1996).

## VI. Conclusion—Building Clear Links between Land Use & Travel Behavior in Policy & Plans

A policy framework has been established linking land use, travel and air quality in the Central Puget Sound Region. Respiratory dysfunction associated with poor air quality is one health consideration that could be addressed through an already adopted formal policy framework. However, there are many other public health predictors, including obesity and physical activity levels, that are impacted by land use and transportation decisions. These outcomes appear to be less connected with adopted policy and with how land use and transportation decisions are currently made. There is a distinct disconnect between adopted policy and practice where health is concerned. The original intent of a great deal of our adopted policy, in a broader sense, is to address health impacts of actions that shape the environment in which we live, work, and play. For example, zoning is the primary tool employed to legally designate how land can be used. States enabled cities and counties in the early part of the 20th Century to use zoning as a tool to protect the health, safety, and welfare of the public. Yet little has been done to demonstrate the connections between this definition of zoning powers and public health.

Regionally significant land use and transportation investment decisions are most often subject to the requirements of the National Environmental Policy Act (NEPA) that stipulates the identification and the mitigation of adverse outcomes. However, even though the original policy language of NEPA speaks to the need for identification of health impacts within the project review process, this is seldom, if ever, done outside of matters of toxicology and exposure. However, the argument to expand this is not a great leap. Concerns with environmental impacts are often centered on how actions can adversely affect our air, water, and other natural systems that predicate human health and quality of life.

The federal, state, regional and county policies described above implicitly or explicitly acknowledge that the success of transportation policies in reducing air pollution will depend to a large extent on whether or not regional land use patterns support the use of alternatives to the automobile. CAAA places major emphasis on changing travel behavior to improve air quality. Air quality problems are persisting while vehicle travel is increasing. Both land use and transportation investments impact travel demand. Land use changes could be effective in reducing vehicle travel, but only within the context of supportive transportation investment decisions.

Washington State's GMA encourages the use of "innovative" land use management techniques to enable attainment of its goals and policies. GMA identifies land use mix, proximity of jobs to housing, population density, building density, and level of transportation service as important potential implementation measures of the Act's requirements (GMA, 1990). Likewise, land use requirements needed to bring about changes in travel behavior are outlined in the STPP, but must be more precisely specified. Vision 2020 is based on the assumption that developing denser, mixed-use centers will result in a less auto dependent travel pattern, and King County's Comprehensive Plan has also called for increased mixed-use development, higher density development and maintenance of an urban growth boundary as methods of reducing VMT and emissions. Testing the effectiveness of these measures has never been more important, given our increasing awareness of the linkages between land use, travel behavior and the health impacts of poor air quality.

These policies also acknowledge the importance of walking and transit as alternatives to automobile dependence, but fall short on specific recommendations for encouraging their use. For instance, ISTEA (and its reauthorizations) have helped to create a renewed awareness of the role that walking and transit can play in accommodating the travel needs of a metropolitan region. However, despite the passage of more than a decade since ISTEA was enacted, planners are only now beginning to become aware of the role that land uses play in travel behavior. For instance, while planners have developed "rules of thumb" about the development patterns that encourage walking as a transportation mode, to date there is little sound empirical basis on which to make these assertions, because land use data traditionally has been inadequate to permit a detailed analysis of how land use patterns influence walking. Similarly, much of the research on transit has focused on the origin end of the trip – how to get people on trains, or which level of residential density is needed to ensure a reasonable farebox recovery on transit investments. While information on the origin end of trips is important, the reality is that regardless of the characteristics of the origin end of the trip, individuals have little reason to use transit unless it takes them close to their actual destination.

A major focus of the research described here is to empirically test the relationships between the land use variables mentioned in these policies, and the travel behavior and trip related emissions produced by regional residents. This study is unique in that for the first time, the relationship between walking and transit usage and a variety of unique and individual land uses can be examined at a disaggregate level. Parcel-level land use data supplied by King County provides the ability to delve deeper into relationships between walking, transit ridership, and land use patterns at both the origin and destination ends of trips. Also, unlike previous studies, this study is able to isolate the effects that mixed land uses have on trip making, independent of the effects of density. Analysis accomplished with this data will put policy makers on a sound empirical footing when making land use and transportation policy decisions. By testing the impact of land use patterns on travel behavior, this project will help identify supportive land use strategies, population and employment densities that are required to foster walking and transit usage, and thus provide a basis for targeted recommendations on regulation and incentive based approaches to land use management. Furthermore, since this project utilizes data gathered from households in the Central Puget Sound area, its results will be directly applicable to subsequent evaluations of the potential for Vision 2020 and Destination 2030 to bring about desired change in the form of urban centers and suburban communities, and the travel behavior that takes place in them. King County's Transit Development Plan currently calls for the allocation of additional transit service in those areas where local governments are aggressively pursuing the implementation of transit-supportive land use policies. Clearly identifying the linkages between land use and travel behaviors such as transit usage will enable the County to take an effective, evidence-based approach to allocation of transit service.

Surprisingly little work has been done to document the effects of specific land use and transportation investment policies on household vehicle emissions. The methods described in this report present a new approach to estimating household vehicle emissions at the trip component or facility link level. We believe that this approach will form the basis of a useful tool for assessing how specific transportation investments and land development projects result in better or worse air quality at the regional scale. Eventually, in-vehicle GPS systems will increase objectivity in the collection of information on travel patterns. However, the widespread use of such methods will be years in the making, and more rigorous methods to assess actual travel choices and their air quality impacts are desperately needed now. This research described here provides a method to increase objectivity in travel data collection practice, in order to provide decision makers with a cost effective source of information on travel behavior – air quality relationships that can readily be applied at project, subarea, and regional scales.

It is also important to develop more informed local planning processes, because, as the research in this report will show, land use decisions made at the local level have a major influence on travel behavior and effect air quality. The research described here demonstrates the linkages between local level land use planning, travel behavior and air quality and provides a basis for integrating local and regional planning and implementation in these areas.

As noted, a considerable policy framework has been established linking land use with transportation and air quality in the Central Puget Sound Region. At all levels of government, linkages between development, transportation investment, and vehicle emissions are written into policy. Growth management theoretically provides a structure for establishing external vertical consistency between levels of government and horizontal consistency between neighboring jurisdictions. Internal consistency between the elements of a comprehensive plan is also a requirement of growth management. However, to date, only a very limited set of measures have been established to objectively determine what constitutes consistency in each of these domains. Particularly glaring is the gap between policy and implementation. Development regulations that control land use, and programming criteria that control transportation investment are considerably out of alignment with adopted policy calling for reduced auto dependence. The research presented in this report documents ways to assess the degree of consistency between policy and actual outcomes in terms of development regulations, programming criteria, and resulting land use decisions and transportation investments.

A considerable set of interlocking policies now exists calling for better linkages between land use, transportation, and air quality, and research in one form or another has been around long enough to document that working towards these linkages will help to meet long held goals of improved transportation and air quality. However, recent evidence further bolsters the argument that more efficient ways to develop our communities are required; in particular, recent findings suggest the need to consider impacts of transportation and land use decisions on climate change and public health.

# Chapter II: Emerging Issues Impacting Community Design—Climate Change and Public Health

## I. Introduction

This chapter explores two emerging sets of issues, climate change and public health, each of which are directly impacted by the design of the communities in which we live. It was determined at the outset that the LUTAQH program should include these two "new" arenas of public concern in order to meet its strategic goals of promoting long term sustainability of the environment and of human health. Unfortunately, current activities are moving us swiftly towards adverse outcomes in both arenas; the amount of carbon dioxide ($CO_2$) being put into the air is increasing significantly and emerging data shows that obesity levels are continuing to increase at an alarming pace. While not addressed in this study, recent research also documents how land use and transportation investments impact traffic safety and crash rates.

Although the United States is not currently a participant in the Kyoto Protocol, the primary international policy framework being used to address global GHG emissions, several states and regions are taking significant steps to move towards increased sustainability. The relationship between those emissions, land use and travel behavior are described here. Likewise, although there is not a coherent set of policies currently linking public health, physical activity, land use and transportation, a discussion of public health and physical activity, travel behavior, and urban form is presented below. Recent research is presented from elsewhere in the U.S. which provides some significant insights into ways King County can strategically move forward with a coherent set of actions that will help to meet adopted goals and policies already mandated within the plans and policies noted in Chapter I.

## II. Climate Change

### A. Potential Impacts

The United Nations Intergovernmental Panel on Climate Change (IPCC), the international panel of the world's leading scientists and scholars on atmospheric science and climate change, recently published an updated assessment of the links between anthropogenic greenhouse gas (GHG)[1] emissions and climate change, the potential effects of climate change, and the potential pathways for reducing emissions and stabilizing atmospheric GHG concentrations. The IPCC has found that climate change impacts have

1 Throughout this paper, $CO_2$ and GHGs may be used interchangeably.

already occurred. These sobering findings include:

- Global average surface temperature has increased over the 20th century by about 0.6°C (1°F); the 1990s was the warmest decade (1998 the warmest year) on instrumental record.
- Global average sea level rose between 0.1 and 0.2m (4-8") during the 20th century.

The IPCC also reports that the global rise in temperature has already affected many physical and biological systems in many parts of the world. Examples include shrinkage of glaciers, lengthening of mid- to high-latitude growing seasons, shifts in plant and animal ranges to higher altitudes and toward the poles, declines in some plant and plant populations, and earlier flowering of trees and emergence of insects (IPCC, 2001).

Further temperature changes will significantly alter precipitation cycles, and fluctuations in both temperature and precipitation are likely to occur unevenly across the globe and over time. Swift, severe changes in weather are possible, and such changes pose a serious challenge to human and ecosystem adaptation. The latest modelling projections through 2100 reveal that the global average surface temperature will increase 1.4 to 5.8°C (2.5 to 10.4°F), and that this will most likely have significant environmental and economic consequences including:

- A rise in sea-level by 0.09 to 0.88 m (about 3.5 to 35 inches)
- Forest migration and loss of biodiversity
- Decreased crop yields leading to potential food scarcity
- Decreased water resource quantity and quality
- Increased risk of infectious disease epidemics
- Increased heat-related mortality
- Increased frequency and severity of storm events
- Increased damage to coastal ecosystems
- Damages to property and infrastructure from increased precipitation and flooding (IPCC, 2001)2

Projected temperature increases are greater and more rapid than the earth has experienced in human history. The severity, rapidity, and variability of the onset of these changes fundamentally challenge human and ecosystem adaptation capabilities.

2 For more information, interested readers may refer to the IPCC web site (www.ipcc.ch).

## B. Trends in GHG Emissions

Current data suggests that global atmospheric concentrations of $CO_2$ have increased 31 percent, from a pre-industrial level of 280 parts per million (ppm) to the current level of 360 ppm. Furthermore, $CO_2$ levels are projected to further increase to 450 ppm by 2025 and 550 ppm by 2050. Failure to significantly reduce global GHG emissions by as early as 2020 could eliminate the ability to achieve atmospheric stabilization of $CO_2$ at levels of 450 ppm or lower (IPCC, 2001). Stabilizing $CO_2$ levels in the atmosphere will require a long-term strategy for several reasons. Changing patterns of human activity and energy use takes time; although GHGs such as $CO_2$ cycle through the atmosphere in about 10 years, the elevated level of $CO_2$ will respond very slowly to any change in input rates. For example, if all emissions of GHGs ceased today, it might take decades before any decrease in GHG concentrations are observed, and several centuries for the GHG concentrations to return to pre-industrial levels. Land and air temperatures and sea level could even increase slightly due to feedback mechanisms already activated, and then would take correspondingly long times to return to pre-industrial levels. Actions we take today will have an important long-term influence on atmospheric concentrations of $CO_2$.

The United States was the largest worldwide emitter of GHGs at 1,909 MMTCE[3] in 2000, and the highest per capita emitter.[4] As Figure 5 illustrates, projections indicate that those emissions will continue to increase.

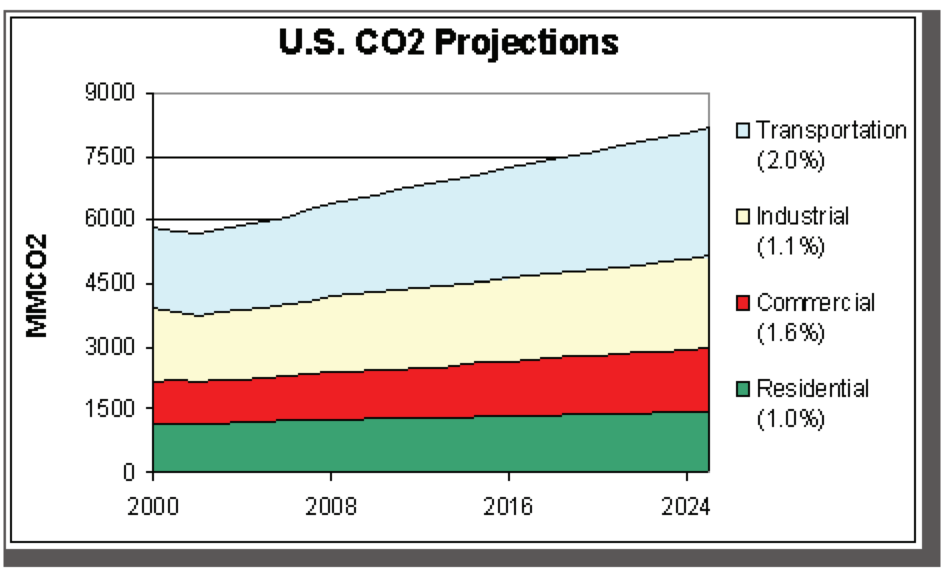



**Figure 5: U.S. CO2 Projections**

(Source: Frank et al 2003a)

3 Million Megatonne Carbon Equivalent

4 Value does not account for removals from carbon sinks (EPA, 2002).

## 1. Trends in Emission Sources

In 2000, fossil fuel combustion accounted for 80 percent of global GHG emissions. Transportation is the fastest growing primary contributor to those emissions (IPCC, 2001); the IPCC estimates GHG emissions from transport increased by 20 percent between 1990 and 2000 – more than any other sector (UNFCC 2003). This trend in transportation emissions is apparent in countries around the world, including the U.S., where the transportation sector currently accounts for almost one-third of U.S. $CO_2$ emissions. Of this amount, cars and light trucks account for almost two-thirds of transportation sector GHG emissions, heavy-duty trucks 16 percent, aircraft 13 percent, with the remainder from marine, rail and other sources (TEDB 2003).

Vehicle $CO_2$ emissions are determined by three key variables: 1) efficiency in vehicle technology, 2) fuel carbon content, and 3) vehicle miles traveled (VMT) or travel demand. While reducing transportation GHG emissions will require progress on all three "legs of the stool," the UNFCCC reports that parties showed a clear preference for addressing energy intensity of vehicles and transport fuel mix (UNFCC 2003). Evidence of this pattern can be seen in the significant progress on vehicle technology in the laboratory by auto-manufacturers and in a few models offered for sale in the automobile market (e.g., Honda Insight, Toyota Prius). There have been some successes in reducing vehicle GHG emissions rates: the European Commission and the European Automobile Manufacturers Association (ACEA) entered into a voluntary, but binding, negotiated agreement to reduce $CO_2$ emissions from passenger cars, and Japanese auto makers lead the world in the production and sales of hybrid-electric vehicles. Despite these successes, most efforts to get efficient or alternatively fueled vehicles into the marketplace have met with limited success.[5] In regards to VMT and travel demand, the UNFCCC reports that, "transport activity and structure were rarely addressed despite an analysis of emission trends that suggested these two drivers contributed most to emissions growth in this sector" (UNFCC, 2003). In fact, in the U.S. and around the world, travel demand is increasing considerably faster than can be offset by technology and fuels alone.

There is an increasing awareness that slowing the growth of vehicular travel demand and diverting travel to alternative modes will be key strategies for reducing GHG emissions from the transportation sector. While research has linked urban form with the generation of Criteria Air Contaminants (CAC's) and their effect on air quality, little work has been done to date that effectively links urban form, travel choice, and the generation of GHG emissions. Fortunately, the actions required to reduce GHG emissions are the same as those necessary to reduce vehicle miles traveled and encourage the development of compact, liveable communities and reduce sprawl.

Sprawling urban regions restrict individuals' travel choices, encourage increased use of motor vehicles

5 California has passed legislation requiring low-GHG cars and light trucks to sold in the State, beginning in model year 2009 vehicles. However, such legislation faces likely challenges, legal and otherwise, from U.S. auto makers and other automobile interest groups.

and increased distances traveled (Silsbe, 2003). Addressing travel demand is thus critical to the reduction of GHG emissions, because, while vehicles only stay on the road for 10 to 15 years, current land use and transportation infrastructure decisions will affect emissions for many decades into the future. Therefore in the long run, implementing non-technical policy options and measures related to reducing VMT are perhaps even more pressing than improving vehicle technology.

## C. Emerging Regional Policy on Climate Change and Emissions Reductions

The Climate Protection Stakeholder Process being led by the Puget Sound Clean Air Agency was initiated in 2003 to identify measures for reducing GHG emissions from energy production, transportation, buildings and facilities, agriculture forests, and solid waste. A significant focus of this stakeholder process is on identifying priority measures for reducing emissions from transportation, since 55 percent of $CO_2$ emissions in the Central Puget Sound Region come from cars, trucks, and buses.

The Transportation and Land Use Working group of this stakeholder process has identified several VMT reduction strategies for consideration. They include land use and location efficiency measures such as infill development, brownfield redevelopment and transit oriented development; the creation of smart growth planning and modeling tools; implementation of urban growth boundaries and density standards; and protection of key open space areas. The Working Group is also considering measures that could promote use of low-GHG emission travel choices. These measures include expansion of transit service, development of bike and pedestrian infrastructure, and implementation of various TDM programs. The process of assessing priority measures for adoption is currently underway. One of the primary assessment criteria for these measures is their ancillary environmental impacts, including public health benefits associated with air quality improvements (PSCAA 2004).

The research results documented in this report demonstrate important relationships between a range of travel behaviors and land use patterns that could be used to inform this stakeholder process.

## D. Emerging King County Policy on GHG emissions reductions

Recommendations from the King County Executive for updates to the Comprehensive Plan (King County 2004) acknowledged that harmful impacts related to climate change are already occurring in the King County region, and can be expected to worsen. The plan update also recognizes that mobile sources such as private automobiles are the single largest source of GHG emissions in the region, and that policy guidance in the Comprehensive Plan should focus on reductions from these sources. Policy directions recommended in the update include:

- Expanding and improving transit service.
- Developing and implementing Transportation Demand Management (TDM) programs.

- Encouraging development of an urban form that increases mix of uses and street and sidewalk connectivity in order to promote and enable use of transit, bicycling and walking (King County 2004).

Again, the research findings described in this report will be directly relevant to the successful implementation of these policies.

## III. Physical Activity and Health: Key Linkages and Concerns

An increasing body of evidence suggests that moderate forms of physical activity, such as walking and bicycling, when engaged in regularly, can have important beneficial effects on public health. Land use decisions and transportation investments have important but for the most part poorly understood influences on physical activity and, hence, public health. Physical activity has long been an important theme in the public health literature but until recently was not addressed in the planning literature. Active or non-motorized transportation are relatively new terms, embodying walking and biking as human powered modes of travel. The transportation planning literature in the U.S. has long been dominated by automobile and to a lesser extent transit-related foci. Congestion mitigation, auto trip generation, and air quality have been central themes. Rarely does the importance of non-motorized transportation occupy a central focus within the literature on travel behavior and land development in America; where research has extended to non-motorized transportation it has been mostly silent on the health benefits of walking and biking as forms of physical activity.[6]

Furthermore, many of the costs associated with increased auto dependence are not accounted for in the public and private investment decisions that create physical environments. To date, where public health issues related to our dependence upon automobiles have been addressed, they have only dealt with vehicle and pedestrian safety issues, and with the effects of automobile emissions on health (Cambridge Systematics, 1994; Surface Transportation Policy Project, 1998). The health costs of decreased physical activity from active forms of transportation have generally been overlooked.

This section reviews current public health, planning, and urban design research to determine, first, how moderate physical activity such as walking and cycling might be critically important exercise behaviors for improving public health; second, how urban form affects the frequency of physical activities such as walking and cycling; and third, how the public health considerations outlined in this paper might be used by planners in the realization of health-promotive environments.

The current lack of awareness of the linkages between built form and overall quality of life, as measured by health, safety, and welfare considerations, suggests the need to rethink public policy approaches to transportation investment and land development. Everyday decisions about our urban form discourage

6 See Cervero 1986; Crane 1996, 1996b; Ewing 1997; Gordon and Richardson 1997; Newman and Kenworthy 1989; Frank and Pivo, 1995; and Moudon et al, 1997 for a review of this research.

physical activity. For example, while a roadway widening may improve vehicular flow, it also can reduce the space allocated to cyclists and walkers, reduce streetscape amenities, and increase hazards associated with higher vehicle travel speeds. The result, often, is that street widenings dampen the desirability of walking and biking as modes of travel (Rapoport, 1987; Untermann, 1987). Public policy interventions designed to improve regional mobility, traffic congestion, and air quality could simultaneously generate significant public health benefits by increasing levels of moderate physical activity.

Figure 6 illustrates a model of the interconnections between public health, physical activity patterns, and the built environment. Physical activity provides a nexus through which these generally disconnected strands of public policy can be combined.

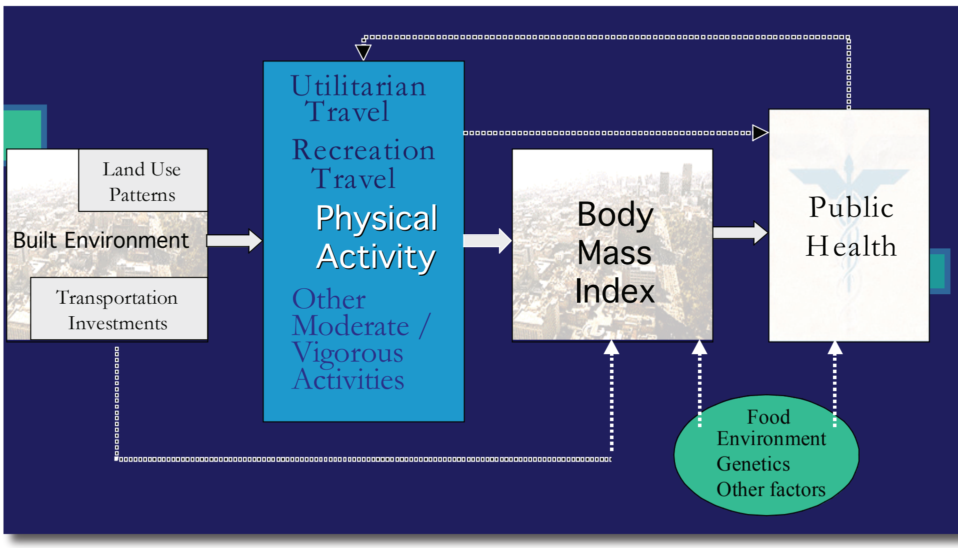



**Figure 6: Built Environment, Activity Patterns, and Obesity**

The dynamic interaction between land development and transportation investments produces built environments that encourage or discourage physical activity for both utilitarian and recreational forms of travel. Physical activity patterns, in turn, are related to public health, but only partially through the influence of activity patterns on body mass index. As conveyed in the above figure, levels of obesity or chronic disease in the general population may also serve to dampen physical activity.

## A. The Relationship between Physical Activity and Health

An exhaustive review conducted by the Surgeon General of the relationships between physical activity and health concluded that substantial health gains could be realized if all persons included regular, moderate physical activity in their lives (U.S. Department of Health and Human Services, 1996). This type of activity was defined as including activities such as 30 minutes of brisk walking or bicycling, 15 minutes of jogging, or 30 to 45 minutes of gardening on most days of the week.[7]

There is general agreement regarding the definition of intensity, duration, and frequency of walking and bicycling in order to meet health standards. In a clinical study of the activity patterns of 17,416 men and women, Stofan et al (1998) reported that people who engaged in brisk walking for 30 minutes on most days of the week ranked in the highest two quintiles for cardiorespiratory fitness. Moreover, the authors discovered that those with the highest cardiorespiratory fitness levels consistently walked more frequently than those with low or moderate levels of activity. In a review of studies, Morris and Hardman (1997) divided the duration, frequency, and intensity goals for walking into two sets of goals: a "basic" target for middle-aged people should be the ability to walk at a normal pace for at least 1.6 kilometers on level ground without fatigue, sore muscles, sweating, or fast breathing; a "more desirable" target was the ability for such people to walk the same distance at the same speed but on a slight incline, also without the symptoms. As a final example, Shephard (1997) agrees that a normal walking pace may provide a sufficient level of intensity for elderly persons, but is sceptical as to whether this is sufficiently intense for young or middle-aged individuals. Additionally, he maintains that bicyclists who ride at an average speed of ten miles per hour are exercising at an adequate level of intensity for the maintenance of good health. Research also shows that those persons at lower baseline physical activity levels may enjoy higher marginal returns to per-unit increases in physical activity than those at higher baseline levels (Pate et al, 1995).

More recently, research has emerged that suggests significant relationships between urban form, physical activity and obesity. A national study led by Reid Ewing with the University of Maryland found that the probability of being overweight or obese and being physically active is significantly associated with overall urban form, as measured at the county level (Ewing et al 2003). A study of 10,898 Atlanta area residents took this relationship between urban form and obesity a step further by assessing the physical environment within a kilometer of each person's place of residence and relating it with their travel patterns and height/weight. The study concluded that each additional half hour spent driving results in a 3 percent increase in the odds of obesity, while each additional kilometer walked translated into a 4.8 percent reduction in obesity. The observations were then quartiled into levels of land use mix, resulting in the findings that each quartile increase in land use mix was associated with a 12.2 percent reduction in the odds of being obese (Frank et al 2004a). The results of these two studies suggest a significant role for transportation investment and land development decisions in the promotion of active living. Perhaps even more to the point are results from the Atlanta SMARTRAQ study, which showed

7 The Surgeon General's recommendation focus on three aspects of physical activity: intensity, duration, and frequency of exercise. According to Bouchard et al (1994), the intensity of exercise relates to the level at which a person's body is working, either in absolute terms (e.g., as a multiple of the individual's basal metabolic rate) or in relative terms (e.g., as a percentage of the individual's maximal heart rate). Duration is the period of actual physical activity. Frequency is the number of sessions engaged in over a week or month.

significant relationships between the overall walkability of the residential environment, as measured by land use mix, density, and street connectivity, and the number of minutes of moderate activity per day (Frank et al 2005b). In this assessment, 357 observations were quartiled into four levels of walkability. Each quartile increase in walkability was found to be associated with a 30 percent increase in the odds of meeting the Surgeon General's recommended 30 minutes or more of moderate activity per day.

The recommendations in the Surgeon General's 1996 report are reflected in national public health goals. In Healthy People 2010, a decadal articulation of national health objectives, the U.S. Department of Health and Human Services (USDHHS 2000) advocates increasing the proportion of Americans who engage in regular, moderate physical activity and decreasing the proportion of Americans who lead a sedentary lifestyle. USDHHS defines moderate physical activities as "activities that use large muscle groups and are at least equivalent to brisk walking," while the term "sedentary" is defined as "a person who is relatively inactive and has a lifestyle characterized by a lot of sitting."

## 1. Levels of Physical Inactivity in the United States

Unfortunately, survey data consistently show that most Americans are not meeting the goals set out in Healthy People 2010. A recent review by Mokdad et al (1999) of data from two primary national health surveys, the Behavioral Risk Factor Surveillance System (BRFSS) and the National Health Information Survey (NHIS), reported that only 20% of the population engages in regular, sustained exercise. Physical inactivity levels generally are higher for minorities, the elderly, the less educated, women, and lower income groups (Mokdad et al, 1999). Other studies report similar findings. In a review of 1990 NHIS data, Jones et al (1998) estimated that only 38% of adults met the Surgeon General's guidelines for moderate physical activity. A review of 1996 BRFSS data by the Centers for Disease Control and Prevention (USDHHS et al, 1999), found that about 30% of the respondents reported no leisure-time physical activity. Moreover, public health researchers report that these low levels of physical activity have remained steady, or have even declined, over the past several decades (Andersen et al, 1999; Marcus and Forsyth, 1999; Mokdad et al, 1999; Prentice and Jebb, 1995).

## 2. The Cost of Physical Inactivity

The public health literature has established physical inactivity as a major health problem, on a par with other risk factors for mortality and chronic disease. To cite one study that provides an indication of the scale of the problem, McGinnis and Foege (1993) estimated that poor diet and sedentary living patterns caused some 300,000 deaths in 1990 (14 percent of all deaths), ranking this as the second leading cause of non-genetic deaths, behind tobacco but well ahead of such well-known causes as firearms and motor vehicle accidents. Epidemiological research has shown that regular physical activity can reduce risk factors for many chronic diseases including coronary heart disease, some cancers, hypertension, diabetes, osteoporosis, obesity, anxiety, and clinical depression (Paffenbarger et al, 1996; Pate et al, 1995).

## B. Influence of Urban Form on Physical Activity

The above considerations have lead public health researchers to concentrate on understanding the barriers to physical activity. In general terms, the literature defines barriers along two lines:

- ***Personal barriers*** are subjective considerations that restrict an individual's motivation or ability to exercise. Frequently cited personal barriers include lack of time, physical inability to exercise, lack of social support, childcare responsibilities and lack of health knowledge (Booth et al, 1997; Myers and Roth, 1997; Sallis et al, 1986). Personal barriers are often conceptualized as perceptive; time constraints, for example, may be as much a perceptive condition as an objective one (Dishman and Sallis, 1994).

- ***Environmental barriers*** are real-world conditions that place restrictions on physical activity, such as the lack of bike lanes on roads. Few public health models have operationalized the role of the physical environment in health to a level of great detail (Sallis and Owen, 1990).

Both types of barriers show up in responses to surveys of why people do not walk or bike more frequently (see for example Go for Green/Environics, 1998). Similar conclusions have been drawn by the Federal Highway Administration in analyses of factors influencing non-motorized mode choice. More recently, analysis of the interaction between the built environment and health related outcomes are beginning to addressing the issue of causation. To date, most of the research is based on cross-sectional data collected on observations at one point in time and does not control for individual preferences for neighbourhood type or travel preferences. Results most often only make inference about association as opposed to causation. Obviously, our preferences shape our behaviour, but we argue so does our choice set, which extends from the physical setting in which we live, work, and play. It is often difficult to separate out the effect of our preferences from urban form in shaping our behavior. The recently released Transportation Research Board /Institute of Medicine report *Does the Built Environment Influence Physical Activity? Examining the Evidence*, No. 282 released in January of 2005 makes this very point:

> *"A growing body of empirical evidence, primarily from cross-sectional studies, supports an association between the built environment and physical activity behavior."* However, the science is *"not sufficiently advanced to support causal connections or identify with certainty those characteristics of the built environment most closely associated with physical activity behavior."*

Among its recommendations for future research are:

1. "[A] continuing and well-supported research effort in this area, which Congress should support in its authorization of research funding for health, physical activity, transportation, planning, and other related areas." The associated research priorities include interdisciplinary approaches

and international collaboration, more complete conceptual models, better research designs (particularly longitudinal studies) that address causality issues, and more detailed examination and matching of specific characteristics of the built environment with different types of physical activity.

2. "[F]ederally supported research funding [that targets] high-payoff but difficult-to-finance multiyear projects and enhanced data collection." Among the highest priorities are "multiyear longitudinal studies, a rapid-response capability to take advantage of natural experiments as they arise, and support for recommended additions to national databases."

## 1. Personal Barriers to Physical Activity

One of the most commonly reported personal barriers to physical activity is lack of time (Booth et al, 1997; Oja et al, 1998; Owen and Bauman, 1992). This may be related to the concept of a fixed household travel time budget. The idea that people are willing to invest a fixed amount of time each day into travel is a phenomenon known as the "law of constant travel time" (Hupkes, 1982). It suggests that an increased travel time requirement for vehicular travel necessarily reduces the time that a household may choose to budget for travel devoted to other, more physically active modes.[8] While vehicle miles of travel (VMT) have generally been increasing over time, evidence has shown that the amount of time spent on commuting to work has remained relatively constant (Pisarski, 1996). This may imply that travelers are using vehicles more frequently to access other, non-work destinations as well – possibly because their urban environments are not conducive to walking or cycling.

## 2. Environmental barriers to physical activity

Although some public health scholars have asserted that changes to the built environment have the potential to increase physical activity much more than policies aimed at influencing individual behavior (e.g., Schmid et al, 1995), environmental barriers to physical activity are poorly understood. The planning literature on this subject suffers from a lack of attention to non-motorized transportation and also from methodological problems extending from limited data (Frank, 2000), but some research conducted in the United States and in Europe suggests that urban form has a powerful influence on walking and biking as well as on overall household activity patterns (Pucher, 1998; Moudon and Hess, 1997; Lawton, 1999).

Little research has been conducted into which specific environmental barriers may hinder decisions to adopt and maintain physically active lifestyles. While a number of studies have found a relationship

8 The notion of an household travel time budget is supported through findings from a household activity-based travel survey conducted in and around Portland, Oregon in 1994, which suggested that households tend to allocate a consistent amount of time to travel, regardless of regional location, or the urban design and transportation characteristics of its environs (Lawton 1999).

between environmental variables such as neighborhood safety and the presence of exercise facilities in neighborhoods (CDC, 1999; Linenger et al, 1991), this line of research is in its infancy.

Environmental barriers may have disproportionate impacts on different sub-groups within the population, most especially for vulnerable groups such as the young and the elderly. The Organization for Economic Co-operation and Development (OECD, 1998) reviewed studies from different member states on the personal mobility of the elderly, and observed that they may restrict their mobility due to safety considerations more than other groups. Such concerns may be related to the particular difficulties that the elderly face when negotiating the urban environment. For example, slower walking speed may restrict an elderly person's ability to safely negotiate crosswalks and other features of the built environment.

Similarly, safety issues dominate the literature on children's travel. Because children perceive the environment in different ways than adults, are smaller in size, and lack experience in traffic situations, children are frequently the victims of traffic accidents. A number of scholars have speculated that parents do not allow their children to travel by themselves due to increased fears of traffic dangers, resulting in fewer trips by children on foot or by bicycle and more trips as passengers in a car (Davis, 1998; Daisa et al, 1996; DiGuiseppi et al, 1997; Hillman et al, 1990; Roberts, 1993). As a result, more and more children are relying on the car for mobility rather than walking and biking. These travel habits are then carried into adulthood.

To enable a clearer understanding of the effects of environmental barriers on physical activity, it will be useful to separately examine components of the built environment – transportation systems, land use and urban form, and micro-scale urban design.

### a) Transportation Systems

Transportation systems provide connections between activities. The characteristics of these systems determine the physical pathways and the relative utility of different travel modes. At the macro or sub-regional level, the supply or capacity for movement across arterials, bikeways, railways, and limited access highways impacts the choice of mode for commuting and other trips between centers or urban areas. Collectively, mode choice between centers or areas of a region and within centers or communities is a synergistic process. For example, transit's regional effectiveness hinges upon the pedestrian environment at the local and neighborhood scale. In addition, the ability to forgo car ownership requires the availability of effective and efficient forms of transit and non-motorized movement.

Within urban centers and communities, the connectivity of the street network and the distribution of space among the different modes of travel within a given right of way impacts the directness and quality of travel. This scale determines one's ability to walk and bike between places of residence, commerce, employment, and recreation.

Generally, there are two types of street networks. Well-connected street networks tend to have smaller blocks, more intersections, and offer more direct movement between activities. The grid pattern is the archetype of high connectivity and is capable of increasing walking and biking by reducing the distance between trip origins and destinations, offering alternative pathways of movement, creating interest, and moderating vehicular travel speeds through the closer spacing of intersections (Southworth and Owens, 1993; Frank et al, 2000).

The high connectivity of a gridded street network is contrasted with the dendritic street network. In this type of system, streets are hierarchical, curvilinear, and often follow land contours. Residential streets loop back upon themselves, terminate in cul-de-sacs and feed into major arterial roads which are designed for heavy traffic volumes and often feature no pedestrian or bicycle amenities. Dendritic networks are characterized by a low number of blocks and intersections per unit of area, increasing trip length, and decreasing route and modal choice (Frank, 2000; Southworth and Owens, 1993).

### b) Land Use and Urban Form

Land development patterns define the arrangement of activities and impact the proximity between trip origins and destinations. Two key characteristics of land development patterns are considered here: density and mix of uses. Density, or compactness, can be measured in terms of the number of persons, households, or employees per acre, square kilometer, or square mile (Dunphy and Fisher, 1996; Frank et al, 2000; Holtzclaw, 1994). There is an extensive body of literature on density and its relationship to travel choice (Cervero and Gorham, 1995; Dunphy and Fisher, 1996; Frank and Pivo, 1995; Holtzclaw, 1994; Kitamura et al, 1994; Steiner, 1994). Higher density has been associated with reduced trip lengths, reduced vehicle ownership (by obviating the need to own a vehicle), and increased mode choice options (Frank and Pivo, 1995).

However, the reliance on density as a measure of urban form is problematic. A review of literature by Churchman (1999) argues that there is little consensus in the planning literature regarding how to operationalize density with precision; over which geographic scale to measure the concept; how to define the goals of densification (e.g., ecological, transportation, housing, or social goals); how to weight the importance of objective density numbers versus the subjective experience of density (e.g., the psychological experience of crowding); and whether higher or lower density is desirable in the first place.

Furthermore, there is a concern that density masks other measures that are perhaps more causal in explaining travel choice. Handy (1996a) argues that "sets of choices"–travel destinations–are correlated with density and serve to shape travel behavior, rather than density itself. Other studies point out that neighborhoods with certain attributes attract individuals who have a preference for walking and bicycling. According to this view, such persons may simply move to neighborhoods that facilitate these activities (Kitamura et al, 1994; Krizek, 2000). Regardless, increased compactness and concentration of uses (density) is a fundamental requirement for shortening distances between activities. However, density alone does not address the presence of, and ease of access to, complementary uses within a walkable distance.

Land use mix is the degree to which difference activities (residential, commercial, retail) are located within close proximity to one another. Research has shown relationships between increased land use mix and reduced trip lengths (Frank and Pivo, 1995); lower level of per capita auto ownership; increased transit usage for the journey to work (Cervero, 1988); and more travel choices for all trip purposes (Apogee, 1998). However, it remains uncertain at what geographic scale mix should be measured and what an "ideal" combination of land uses would be within differing urban settings.

Collectively, density and mix of uses determine the geographic proximity between activities, whereas connectivity of the street network determines the directness with which one can travel between activities. These three factors together help to determine the rationality of walking and cycling as mode choices.

### c) Micro-Scale Urban Design

Pedestrians and cyclists are more sensitive to urban design features of the built environment than the motorist. Rapoport (1987) believes that the critical determinant of the influence of urban design features on the traveler is the numbers of noticeable differences on the streetscape, which is a function of the rate at which a person moves through the built environment. Motorists have a limited ability to process detail in the environment because speed demands concentration; therefore, the ideal environment for a motorist is low in complexity. Conversely, pedestrian and bicycle travel, being much slower, affords the ability to notice differences in the streetscape. A rich pedestrian environment, therefore, is one that maintains the pedestrian's visual and sensory attention. Streets that are abrupt, irregular, complex, and changing will be more highly valued by a pedestrian (Rapoport, 1987). Finally, urban design features at the neighborhood level, including the placement and design of buildings, parking lots, and other features in the neighborhood (Owens 1993) also impact the desirability of non-motorized travel.

Streets with ample sidewalks, bike lanes, and crosswalks upon which pedestrians and cyclists can travel will be perceived as safer to these non-motorized travelers. Their perception of safety is influenced also by the speed at which automobiles travel along the street itself (Handy, 1996b). Over the last half-century, road design standards have favored high-speed, motorized travel that discourage promotion of walking and biking for mobility and recreational purposes (Ewing, 1994; Hess, 1997; Southworth, 1997; Southworth and Ben-Josef, 1996; Untermann, 1987).

## 3. Planning for Health-Promotive Urban Environments

Given the growing awareness of the linkages between land use, physical activity, and public health, there is considerable motivation for local governments to identify ways in which transportation and land use decisions and investments can positively influence mobility and accessibility, physical activity, and quality of life. The concept of a health promotive environment, described above, is one way in which planners can re-frame their land use and transportation decisions to ensure that physical activity is promoted in everyday life. In addition, it is important that the promotion of physical activity through good urban design make it into the policy sphere. One way this could occur is through by requiring the creation of health impact statements as part of planning or project approval processes. More generally, planning scholars have an important, and perhaps underestimated, role in crafting a research agenda that reflects the connections between public health, non-motorized transportation, and the built environment - so that policy development and plan implementation can be grounded in empirically based findings on these connections.

### a) Emerging Public Health Policy in the King County Comprehensive Plan

King County recognizes physical inactivity and obesity as interrelated and significant public health concerns. Executive recommendations for revisions to the Comprehensive Plan (King County 2004) explicitly acknowledge the linkage between low density, auto-oriented development patterns and physical inactivity. The recommended plan update specifically notes that individuals are more likely to walk to a destination if it is within half a mile of their location, and cycle to destinations if they are within two miles. The plan update identifies a number of land use measures that can be used to encourage regular walking and cycling as physical activity. These proposed measures include:

- Increasing housing density by focusing future growth in the UGA, in order to enable more efficient transit service and support the location of shops and services near to homes.
- Providing neighborhoods with safe sidewalks and trails, and increasing street connectivity and safety for cyclists.
- Encouraging mixed use developments and allowing neighborhood serving shops and services in residential areas.
- Developing complete urban centers that promote a sense of safety and are pleasing and stimulating to walk and cycle through.

In reference to White Center, a major unincorporated activity center in King County and one of the case study subjects of this research, the recommended plan update proposes the following strategies:

*"In the White Center Unincorporated Activity Center, new major residential developments should include low-impact design features and should promote public health by increasing opportunities for physical activity in daily life. The development should include: safe walkways and bicycle lanes with access to commercial areas, schools, and community facilities; trails; and pocket parks." (King County 2004)*

# IV. Conclusion

## A. Linking Land Use to Action on Climate Change

While there is currently no comprehensive set of policies addressing climate change at the federal or state level, there is widespread acceptance that the issue is important and requires urgent attention. All evidence points to transportation as a primary source of anthropogenic GHG emissions, and it is clear that reductions in vehicle miles traveled, not just improvements in vehicle technology, will be required to bring about major reductions in these emissions. Fortunately, a forward-looking policy response to climate change is developing at the regional and county level which reflects this need for action.

The Puget Sound Climate Protection Stakeholders Process is developing a set of measures to reduce GHG emissions. In its work so far, the Stakeholders Process has drawn a clear link between land use and travel behaviors such as VMT, and has explicitly acknowledged the need for better planning tools with which to select measures most effective at reducing emissions. The research results documented in this report demonstrate important relationships between a range of travel behaviors and land use patterns that could be used to inform this stakeholder process, to select effective measures for VMT reduction, to develop planning and modeling tools, and to identify a broader range of ancillary benefits (such as increased physical activity) associated with various measures.

King County is also moving ahead to take action on climate change, and is currently in the process of revising its Comprehensive Plan to address climate change issues. Recommended changes to the plan focus on expansion of transit and TDM programs, and importantly, changes to land use and urban design which will enable and support use of transit and non-motorized modes. The findings from LUTAQH will be directly relevant to this process, because they will facilitate the development of policy guidance that is evidence-based and focused on efficient and effective measures.

## B. Clarifying the Influence of Land Use on Public Health

The connection between public health and travel behavior is also increasingly well documented. As shown in Figure 7, this report argues that the built environment, our transportation systems and public health form a complex system of matrices and influences. The findings of the research described here will help to determine which aspects of land use and urban form have the greatest influence on physical activity. This information will be of use to planners wishing to develop more health-promotive urban environments.

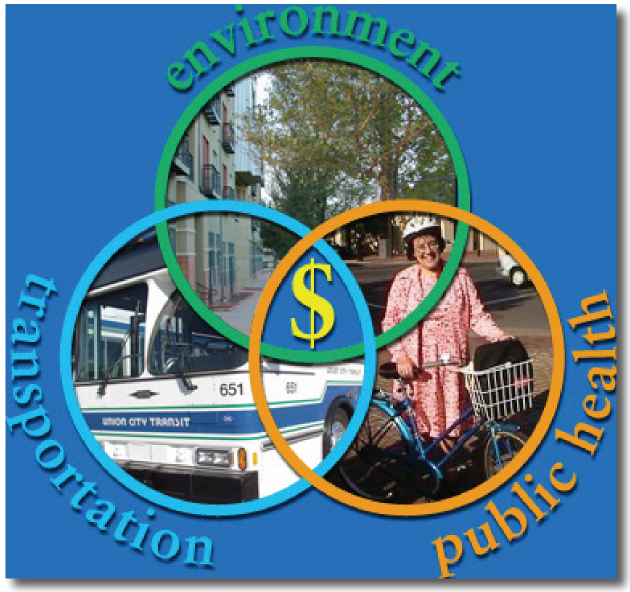



**Figure 7: Relationship between Health, Transportation, and the Built Environment**

King County has taken a leadership role in this area by building explicit links between public health and land use planning into its policy guidance. Recommended changes to the County's Comprehensive Plan include a number of detailed land use policies which aim to increase use of walking and cycling as daily travel modes. The identification of land use-travel behavior relationships in this research project will be directly relevant to the implementation of these policies, the specification of requirements for transit service allocation, and the development of urban environments which encourage and enable walking and cycling as regular daily activities.

The following chapter of this report will provide a description of the methodology used in identifying key land use-travel behavior relationships. Later chapters will go on to document these relationships at the County level, consider their use in land use planning in three case study settings, and discuss their implications for County-wide land use and transportation policy.

# CHAPTER III: Database Development

## I. Overview

This chapter outlines the methods used to develop the data used in the LUTAQH analysis. It first describes the process of data collection and database development for measuring urban form around the home and work locations of County residents. It further conveys the process by which the travel behavior and demographics of the residents themselves are linked with this urban form data. Travel behavior, land use, and urban form variables developed from this database are then defined. Methods used to model the trips reported by regional residents in the Household Activity Survey and associated emissions are conveyed. These emissions are estimated for those portions of trips on freeways, arterial routes and local roads. Finally, methods used to analyze relationships between levels of physical activity and land use and urban form near the household.

## II. Land Use, Travel Behavior, and Household Demographics Database Development

### A. Data Sources

The research team developed the transportation and land use databases by synthesizing data from a variety of sources, including:

- Parcel level land use data for King County, which includes information on the size, shape and land use classification of each individual parcel in the county.
- Travel Survey data from the 1999 Puget Sound Household Activity Survey. This survey provided detailed trip-level data for 6040 households located in King, Pierce, Snohomish and Kitsap Counties. Of these households, 3259 were located in King County and had complete and valid records. The survey includes 101,766 trips with information on origin and destination coordinates, trip purpose, travel mode, reported trip distance, and trip start and end times. In addition to these attributes, the survey includes unique person and household identifiers which allow for a link to be established between the travel behaviors described in that survey and information obtained through associated surveys administered at the person and household level, such as personal annual income, age, and educational attainment, household demographics such as vehicle ownership, and street addresses for residential and employment locations.
- Physical health data was provided from two sources, the NIH funded Neighborhood Quality

of Life Study (NQLS) led by Dr. James Sallis and the "Silver Sneakers" survey program led by the Group Health Cooperative. With physical activity and obesity levels for 16 communities in King County, the NQLS data represents among the most sophisticated and comprehensive datasets to date linking the built environment with public health. Approximately 75 persons in each of 16 communities within the County were surveyed for a full week at two separate intervals to get an accurate assessment of their levels of physical activity as measured with an accelerometer. Urban form measures were developed around each participant's place of residence using a one kilometer network buffer. Participants were between the ages of 20 and 65. Figure 8 maps the 16 communities included in the NQLS study.

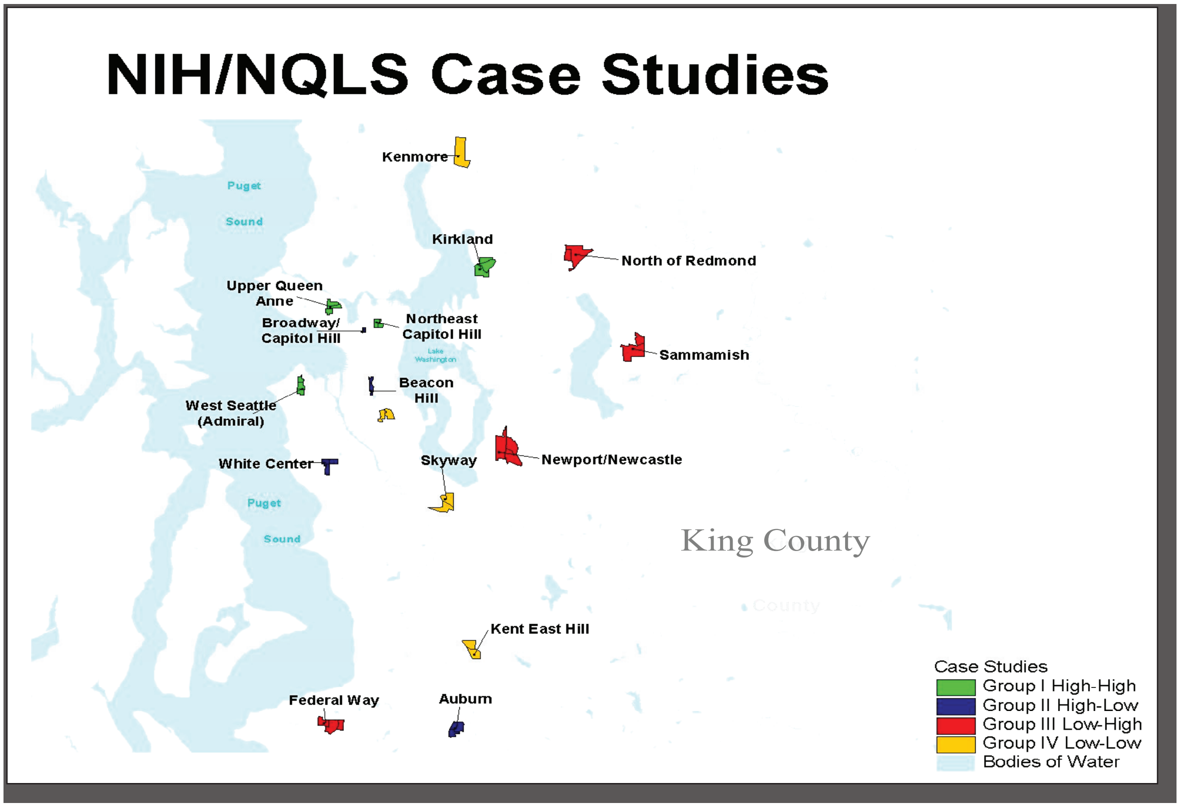



**Figure 8: Sixteen NQLS Communities**

Contrasting the NQLS community level data collection is the Silver Sneakers survey, which provides detailed health and activity data for 2,859 individuals in Washington and Oregon who are members of group health plans, receive Medicare, and are between 55 and 75 year old. 673 survey respondents were located in King County and had complete and valid records. The Silver Sneakers survey was conducted by Group Health Cooperative in conjunction with the University of Washington in 1999.

## B. Database Creation

Databases were constructed using a set of steps outlined in the following section. Objective measures of urban form were developed in a Geographic Information System (GIS) and spatially linked with household level travel, demographic, and attitudinal data. This process is described in greater detail in the following technical discussion.

## 1. Creating a Master GIS Database

The first step was to create a master GIS database inclusive of parcel level land use data, census geometry, transportation network information, and other spatial data. Figure 9 provides a visual description of a set of households in Seattle and the ¼ mile "behavior sheds" (buffers) selected around each household.

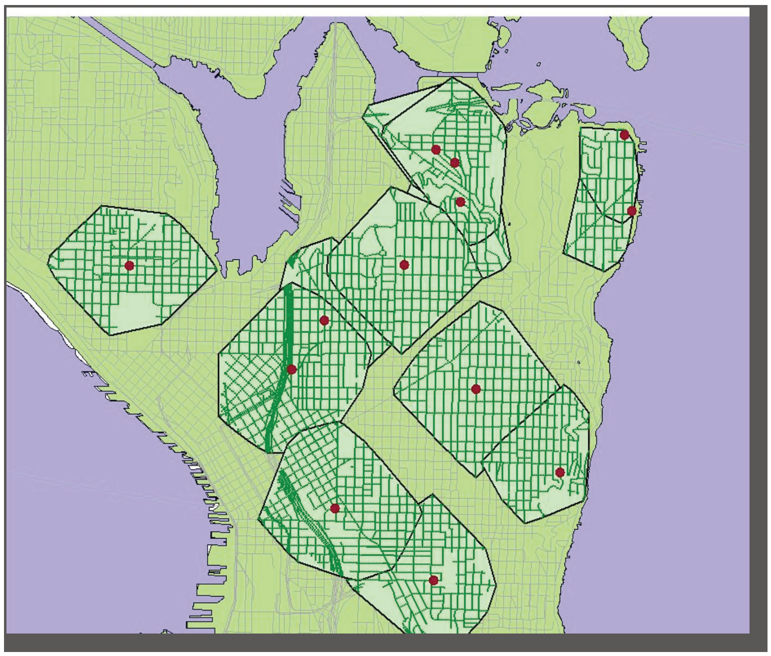


**Figure 9: Integrating Household & GIS Data**

The most complex of these databases was the assemblage of the parcel data. For example, after evaluating the parcel data, the research team discovered that certain land uses, such as apartment complexes and commercial office parks, were divided into multiple subparcels within the data set, each containing the attributes of the entire parcel. Due to the potential to overestimate the size of these types of parcels, these subparcels were dissolved into a single master parcel using GIS. This master parcel shapefile provided the research team with the ability to accurately determine the size of the parcel, the number of commercial or residential units located on the parcel, and other attributes associated with the parcel.

### a) Determining the Spatial Location of Survey Households

After identifying households from both the Household Activity Survey and the Silver Sneakers Survey with locations in King County, the second step in this analysis was to spatially locate the households for which parcel-level data was available. The Household Activity Survey provided the exact latitudinal and longitudinal coordinates of the households, allowing their locations to be quickly plotted in GIS.

The Silver Sneakers Survey, however, provided only household addresses. To locate these households, the research team used a process known as "address-matching" or "geo-coding" to associate the households to their correct locations along the street network in the GIS database. While a useful means for locating households, address matching is often an inexact process. To ensure the locational accuracy of the Silver Sneakers households, the research team address-matched all households that had an ArcView match rate of 75 or higher, which included 508 of the 760 households. The remaining 252 households that could not be accurately address-matched were manually located by cross-referencing household addresses with both the shapefile of the regional road network and standardized commercial map products of the region, including the 2001 edition of *The Thomas Guide*. Once the locations of these households were determined, they were manually plotted in GIS, and the household-level attributes were associated with the newly-created point. Of these 252 households that did not address-match in ArcView, 23 households could not be plotted due to inaccurate address information, forcing their records to be withdrawn from the sample. Ultimately, 737 of the 760 households could be accurately geo-located, 673 of which had complete and usable records.

### b) Identifying Land Use Characteristics Around Survey Households

Determining household locations permitted the matching of household and individual data with the geographic data (especially land use) that surrounded each household. To do so, it was necessary to construct an analysis buffer around each household. The purpose of this buffer was to delineate the geographic area around each data point that was likely to influence the resident's behavior. For this project, we sought to capture the land uses that were within a comfortable walking distance, 0.25 miles (1,320 ft) from each household. To confirm the validity of this distance as a measure of a comfortable walking distance, we examined the distribution of walk trips from the Puget Sound Activity Survey. The average walking speed for residents of the Puget Sound area was 2.4 miles per hour, indicating that the average resident could access most destinations within a quarter mile of their home in roughly 6 minutes, which the researchers concluded was a reasonable expectation. Figure 10 shows average walk speeds for survey respondents in the Puget Sound Household Activity Survey.

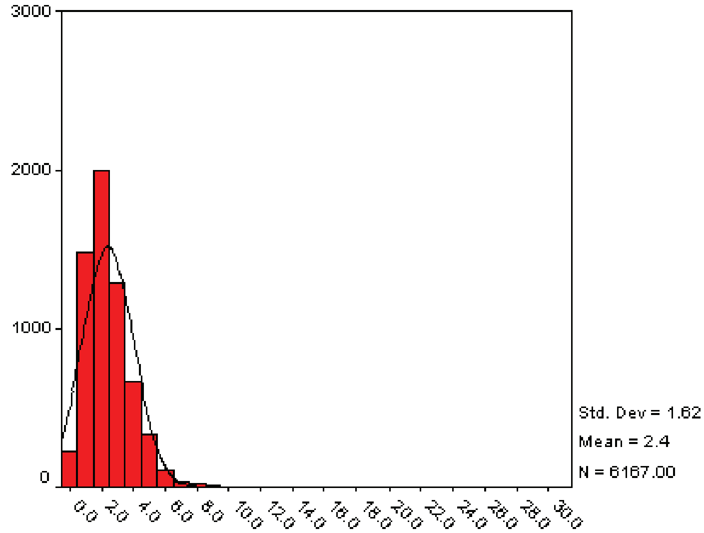



**Figure 10: Walking Speeds for Activity Survey Respondents**

On average, participants in the Puget Sound Household Activity Survey walked 2.4 miles an hour. The quarter-mile network buffers used in this study represent the actual land uses that an individual can access within a 6-minute walk from their home.

To identify the land parcels accessible within a quarter-mile walking distance from survey households, the research team created quarter-mile network buffers around each household. Unlike "crow-fly" buffers, which simply encircle a home location in a quarter-mile radius, network buffers capture the area reachable within a quarter-mile distance from the home along the actual transportation network. Figure 11 provides a comparison of crow-fly versus network buffers in connected and disconnected community environments.

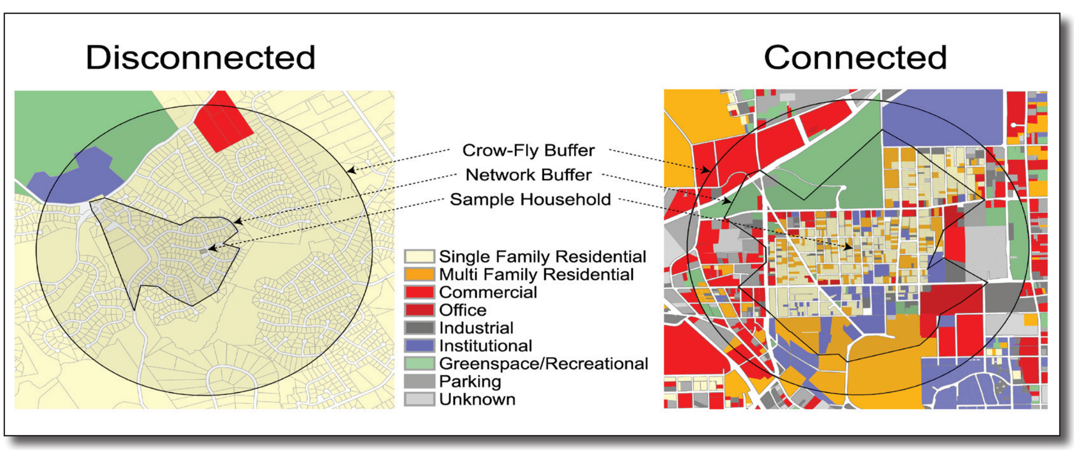



**Figure 11: Buffers in Disconnected and Connected Community Environments**

Source: American Journal of Preventive Medicine 2004

Once these buffers were created, an intersect overlay analysis was used to identify all of the parcels that were located within each of the network buffers. The network buffer assumes the travel time needed to access a location is the key consideration for inclusion in a buffer. If a parcel fell within the buffer area, it was included in the land use database for that household's buffer, even if only a portion of the parcel was actually inside the buffer. Researchers assumed that an individual could fully utilize the benefits of a site if he/she was able to access a portion of the site, because if the attraction is partly accessible within the specified travel distance, it is likely that the individual will use the entirety of the attraction, not just the portion included within the buffer. To illustrate this assumption using a real world example, although only a portion of a grocery store may be located within a quarter mile distance of a person's household, the ability to access this store within a given travel distance allows the individual to utilize the entirety of the store, rather than the portion actually inside the buffer.

### c) Classification of Parcel Land Uses within a Buffer

The land use characteristics for the parcels captured in each buffer included the parcel size, gross building area, rentable building area, and number of building units in each parcel. This information was aggregated to the household level buffer according to the 26 land use categories listed in Table 1 below.

| | | |
|---|---|---|
| Mobile Homes | Single Family | Residential |
| Single Family | | |
| Multi-Family 2-9 Units | Multi-Family | |
| Multi-Family 10 or More Units | | |
| Office Park | Commercial | Commercial |
| Low-Rise Office | | |
| High-Rise Office | | |
| Misc. Office | | |
| Industrial | Industrial | Industrial |
| High Tech | | |
| Large Retail | Large Retail | Retail |
| Neighborhood Retail | Small Retail | |
| Misc. Retail | | |
| Passive Recreation | Passive Recreation | Recreation/Entertainment |
| Art Galleries and Museums | | |
| Playgrounds | Active Recreation | |
| Public Parks | | |
| Health Clubs | | |
| Restaurants and Bars | Food Sources | |
| Convenience Stores | | |
| Grocery Stores | | |
| Fast Food Restaurant | | |
| Institutional | Institutional | Institutional |
| Civic | | |
| Agriculture | Agriculture | Agriculture |
| Manufacturing | Manufacturing | Manufacturing |
| Fine-Scaled | | Course-Scaled |

**Table 1: Scales of Analysis**

Using the finer-scaled land use categories permits a comprehensive examination of the role that individual land uses have on physical activity and travel behavior.

The process of buffer creation was duplicated at various scales for use in analysis of relationships between vehicle travel and land use and urban form. Buffers were also created around respondent's reported employment locations. More detail is provided on these processes under the discussion of individual mode results in the next chapter. Examples of residential and employment buffers are provided in Figure 12 for a hypothetical household located on Queen Anne Hill, and a corresponding employment location in the Seattle CBD.

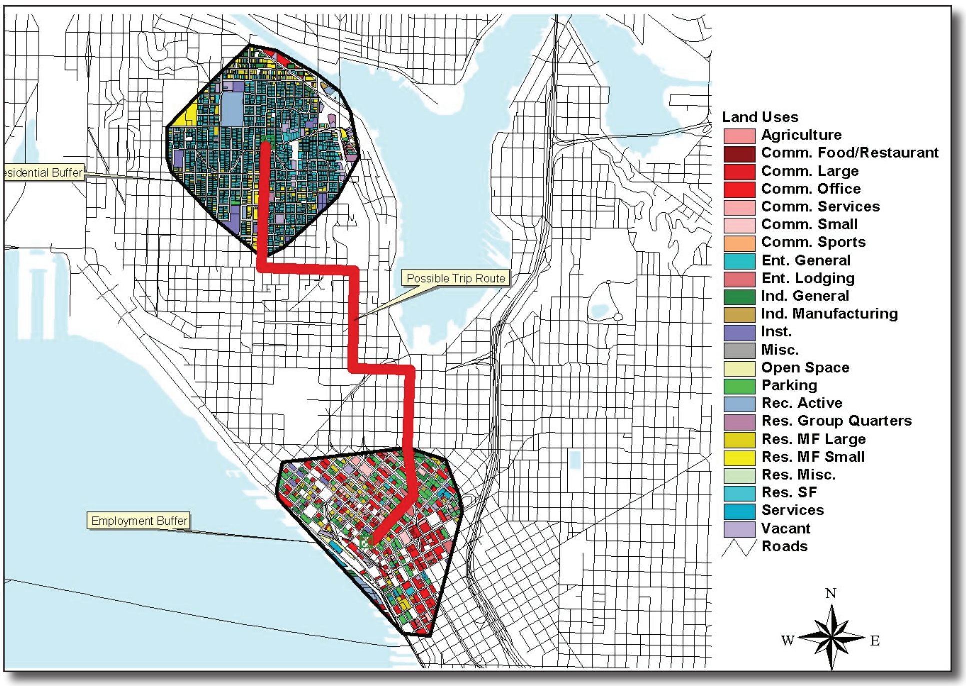



**Figure 12: Residential & Employment Buffers**

# III. Measuring Urban Form

A series of land use variables were developed based on known and hypothesized relationships between urban form, travel behavior, and physical activity. Independent variables of urban form were developed sequentially. Once basic relationships were identified, more elaborate land use variables were developed to further define these relationships and to better explain as well as predict the relationships between land use, travel behavior, and physical activity.

## A. Land Use Variables

As described earlier, the parcel data for King County allowed several different land use measures to be used as independent variables in this preliminary analysis: the number of different land uses (attractions) accessible within a respondent's household or employment buffers, the total parcel area devoted to individual land use in the buffers, and the actual rentable building area for each land use in the buffer. Each of these measures corresponds to a land use dynamic of interest to the practicing planner, and each captures a different element of land use mixing:

- *The number of different land uses (individual attractions)* captures the total unique destinations accessible within a household or employment network buffer. More unique attractions indicate that an area has a more diverse, and potentially more interesting, streetscape. This measure emphasizes the role that the variety of attractions, such as neighborhood retail, has on travel behavior. Ignoring the actual size of the uses themselves, this measure assumes that more unique attractions in a land use category found within a buffer better explains travel behavior than does the total square footage of the attractions themselves. The downside of this measure, however, is that it fails to capture the quality of the attractions themselves. Larger retail stores, for example, can offer a variety and selection of merchandise that would be unavailable in smaller stores with fewer useable square feet of floor space.

- *The rentable building area (square footage)* of a use indicates the actual density of a particular use within a buffer area. Using retail space as an example, it assumes that having 100,000 square feet of retail floor space within the household's buffer area is a better predictor of travel behavior than having 50,000 square feet. The measure does not, however, capture the effects of fine-grained development patterns. For example, assuming two neighborhoods have 50,000 square feet of retail space, one with the uses broken up into multiple small shops that comprise a downtown core area, and the second with a single, larger retail store, the measure treats the retail uses equally, disregarding the physical configuration. Part of this deficiency in the measure was overcome by separating retail uses into "large retail," which are retail uses with 100,000 square feet or more of floor space, and "neighborhood" retail, which has less than 100,000 square feet of floor space.

- *The total parcel area* measures the total parcel area committed to particular uses, and gives a sense of gross area devoted to uses in a buffer, independent of the number of uses or the rentable floor space of those uses. This measure is somewhat equivalent to a description of conventional zoning by use, and while it may be useful in explaining the role that zoning has on travel behavior, the measure captures neither the diversity of land uses nor their density within a buffer.

As described in Figure 13, these three ways that land use can be measured provide complementary perspectives on land use dynamics in neighborhoods.


**Figure 13: Land Use Triangle**

However, while each of these ways in which land use can be measured provides useful information, none is expected to provide a complete picture of the effect of land uses on travel behavior, and some may be more useful for explaining particular types of travel behavior than others. For example, the number of commercial or retail destinations within a community was found to be more closely associated with pedestrian travel than with other modes. Conversely, the amount, or square footage, of commercial and retail use was a better predictor of transit ridership, which makes sense because this is a closer correlate of the critical mass of development and number of potential transit riders within a given corridor. Also fundamental to measuring mixed use is the way in which different uses are co-located in space, and how well the uses complement each other. Considerable research has gone into this topic to date - however, no conclusion has been reached as to what constitutes an optimal level of mix. The concept of an optimal mix of uses depends upon the purpose of travel, the travel mode being assessed, and the scale at which mix is being measured. What is most unique about this study is its ability to assess discrete associations between measures of travel behavior and physical activity and measures on each side of the land use triangle.

Table 2 summarizes the distribution of land uses in King County by the number of parcels by land use, the useable square footage in each land use type, and the total acreage in each land use type. Single-family residential is the dominant land use type in King County, both in terms of number of parcels as well as total acreage.

Land Use Distribution

| | Number of Parcels | Leasable Square Footage | Total Acreage |
|---|---|---|---|
| **Single Family** | 79.1% | 47.0% | 50.1% |
| **Multi-Family** | 8.5% | 22.6% | 7.6% |
| **Vacant** | 6.4% | N/A | 15.4% |
| **Retail** | 1.6% | 6.2% | 2.9% |
| **Entertainment** | 0.6% | 3.3% | 0.9% |
| **Recreation** | 0.2% | N/A | 6.4% |
| **Office** | 1.0% | 10.7% | 1.8% |
| **Industrial** | 1.1% | N/A | 5.3% |
| **Institutional** | 0.6% | 6.7% | 3.0% |
| **Educational** | 0.2% | 3.6% | 5.4% |
| **Open Space** | 0.0% | N/A | 0.1% |
| **Misc.** | 0.8% | N/A | 1.2% |

**Table 2: Land Use Distribution**

## 1. Density Variables

In addition to the land use information for the individual parcels defined in the database, the following independent variables for residential, employment, and street network density (connectivity) were developed:

### a) Gross Residential Density

Gross residential density measures the total number of residential units in the buffer area. However, while useful for understanding the total number of dwelling units in a given area, gross residential density fails to account for true residential densities in areas where there are multiple land uses. Gross Residential Density is defined in Equation 4-1 as:

$$\text{Gross Residential Density} = DU_{tot}/Acre_{buff} \qquad (4\text{-}1)$$

Where: $DU_{tot}$ = the total number of dwelling units in the buffer

$Acre_{buff}$ = the number of acres in the buffer

### b) Net Residential Density

Net residential density provides a measure of the total number of residential units incorporated in areas designated as residential. As such, it provides an "apples-to-apples" measure of the residential density in a given network buffer and is defined in Equation 4-2 as:

$$\text{Net Residential Density} = DU_{tot}/Acre_{res} \qquad (4\text{-}2)$$

Where: $DU_{tot}$ = the total number of dwelling units in the buffer.

$Acre_{res}$ = the number of residential acres in the buffer.

### c) Net Employment Density

Employment density is a very important predictor of transit use and travel behavior in general. This measure of density characterizes the degree of compactness of employment centers within the Central Puget Sound Region. Net employment density was developed through the application of Employment Security Data provided from the Puget Sound Regional Council. Employment Security Data provides the number of jobs per reported employment site, and was aggregated to the Traffic Analysis Zone (TAZ) by job type by the PSRC. Parcel level land use data described above was used to measure corresponding land areas within a TAZ[1] with a given category of employment. For example, the number of retail

1 TAZs largely correspond with Census Tracts, except in urban centers where they are broken into smaller units of geography.

jobs was divided by the land area in retail use, resulting in a ratio of jobs to land area for specific types of employment. Ultimately, the total number of jobs divided by the total area within a zone that is in commercial or non-residential use was used to characterize the level of employment density of a given zone as defined in equation 4-3 below.

$$\text{Net Employment Density} = \text{Jobs}_{tot}/\text{Acre}_{emp} \quad (4\text{-}3)$$

Where: $\text{Job}_{tot}$ = the total number of jobs in a given TAZ.

$\text{Acre}_{emp}$ = the number of employment acres in the TAZ

### d) Intersection Density

Intersection density is a measure of network connectivity. Increasing the number of intersections in an area provides travelers with more route options as well as the ability to select routes that minimize overall trip distance. Thus, higher intersection densities correspond to increased destination accessibility - the more intersections in a given land area, the greater the number of attractions that can be accessed within a specified distance. Figure 14 conveys the location of the true intersections (with 3 or more legs) around survey households.

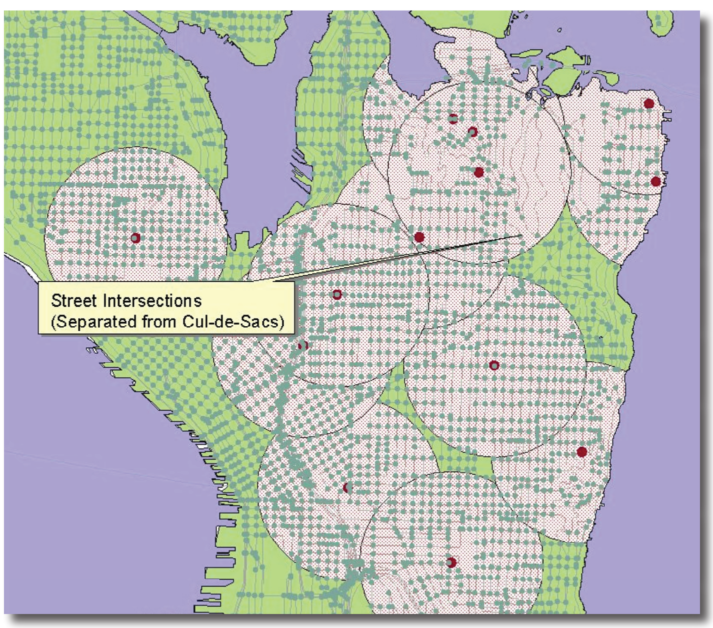



**Figure 14: Locating Intersections**

The number of intersections in the buffer was divided by the total number of kilometers within the network buffer, as defined in Equation 4-4.

$$\text{Intersection Density} = Int_{tot}/KM_{buff} \quad (4\text{-}4)$$

Where: $Int_{tot}$ = the total number of intersections in the buffer.

$KM_{buff}$ = the number of kilometers in the buffer.

Once urban form variables were constructed, the research team ran a series of statistical tests to determine their relationship with the four key measures of household travel behavior: percentage of household walk trips, percentage of household transit trips, VMT, and VHT.

#### e) Mixed Use

The mixed-use factor takes into account the number of different land uses among six categories (education, entertainment, single family residential, multi-family residential, retail and office) as well as their relative amounts, in terms of building floor areas to total buffer land area. Building floor area data, by use type, from the parcel level land use database were aggregated to the one kilometer buffer level. A greater mixed use value means more even distribution of the relative amount of floor area for the land uses present. The formula that was used is:

$$\text{Land use mix} = A/(\ln(N))$$

where:
$A = (b_1/a)*\ln(b_1/a) + (b_2/a)*\ln(b_2/a) + (b_3/a)*\ln(b_3/a) + (b_4/a)*\ln(b_4/a) + (b_5/a)*\ln(b_5/a) + (b_6/a)*\ln(b_6/a)$

where:
a = total square feet of land for all six land uses present in buffer
$b_1$ = square ft. of building floor area in education uses
$b_2$ = square ft. of building floor area in entertainment uses
$b_3$ = square ft. of building floor area in single family residential uses
$b_4$ = square ft. of building floor area in multifamily residential uses
$b_5$ = square ft. of building floor area in retail uses
$b_6$ = square ft. of building floor area in office uses
N = number of 6 land uses with FAR > 0

# IV. Measuring Travel Behavior

## A. Regional Household Travel Survey Methodology

The Puget Sound 1999 Household Travel Survey reported an accuracy rate of $\pm$1.3 percent at the 95 percent confidence interval, based on the final random sample size of 6000 households across the four counties. It obtained a 30 percent response rate, which is comparable to other similar household travel surveys.[2] The survey used a probability sampling method, with sampling targets based on household size and vehicle ownership, which enabled it to overcome non-response bias in large households and households with no vehicles, two subgroups that historically have had high non-response rates in similar surveys.

The Household Travel Survey sample showed similar distributions to the 1990 census for household size and vehicle ownership. However, the sample under-represented low-income households and over-represented high-income households, compared to the census. It also under-represented apartment dwellers, and over-represented those who dwell in single-family homes. Under-representation of low-income segments of the population is a problem common to many surveys explained by increased difficulties in recruiting lower socio-economic status (SES) households.

## 1. Demographic Profile of the Sample and Comparison to Regional Population

As shown in Table 3 below, Travel Survey respondents were more likely to be White than the population of the four county region as a whole (92 % vs. 82%), live in slightly smaller households (2.4 vs. 3.1 persons per household), were slightly more likely to be female, and had a higher median age. When compared against their proportions in the 2000 Census, populations classified as Black or Asian were under-represented in the Travel Survey.

**Demographic Characteristics**

| | Activity Survey | 2000 Census |
|---|---|---|
| *Average Household Size* | 2.4 | 3.1 |
| *Percentage White* | 92% | 82% |
| *Female* | 52% | 50% |
| *Median Respondent Age* | 40 | 35 |

**Ethnic Makeup of Survey and Region**

| | White | Black | Asian | Native American | Other |
|---|---|---|---|---|---|
| **Activity Survey** | 92.3% | 2.0% | 3.8% | 1.1% | 0.8% |
| **2000 Census** | 82.2% | 5.1% | 9.1% | 1.2% | 2.4% |

Source: Activity Survey Data and 2000 U.S. Census

**Table 3: Comparison of sample to the 2000 Census**

Differences in ethnic distribution between the sample and census population may be related to income-response biases and language barriers in the survey process as noted above. Further details on the methodology of the Puget Sound Household Travel Survey can be found in that study's final report.[3] A brief description of the survey sample age, income and vehicle ownership distribution are

2 The response rate was calculated as a product of the recruitment rate (46%) multiplied by the completion rate (67%).

3 Puget Sound Regional Council. 1999 Puget Sound Household Regional Travel Survey. Draft Final Report (December

provided in Figure 15 through Figure 17 respectively.

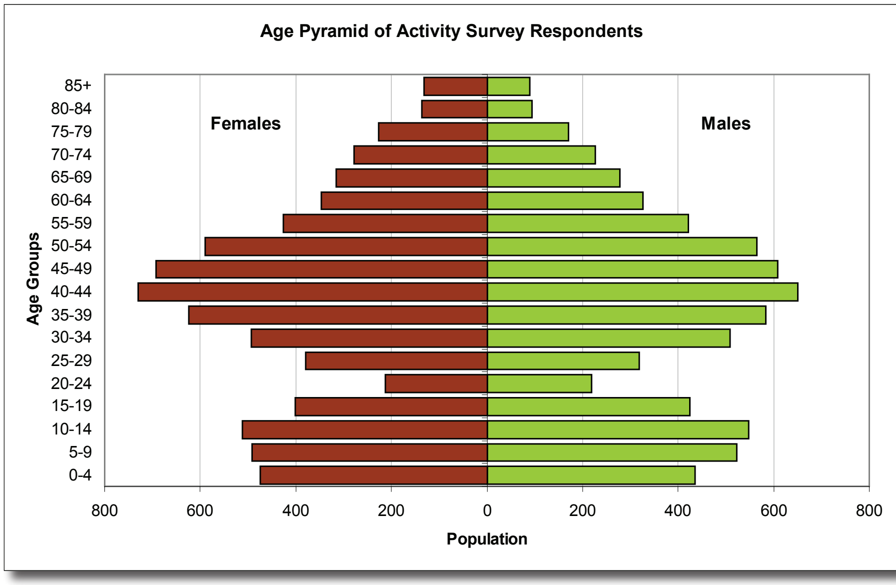



Figure 15: Age Pyramid of Survey Respondents

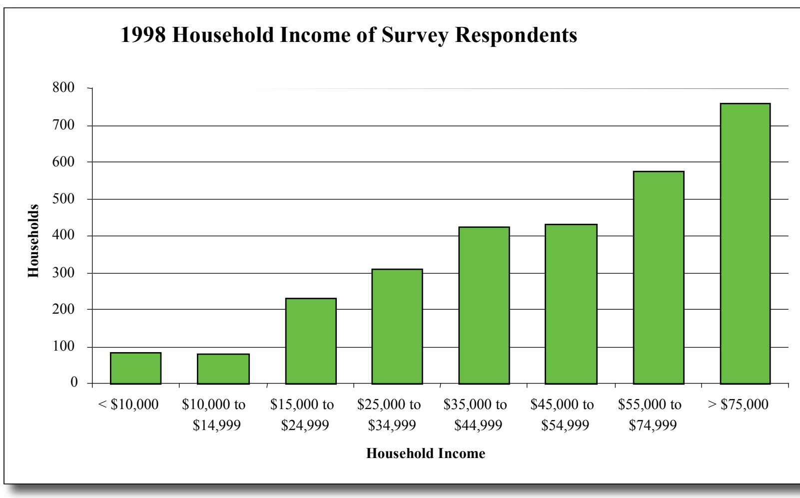



Figure 16: Household Income of Survey Respondents

1999) NuStats Research and Consulting.

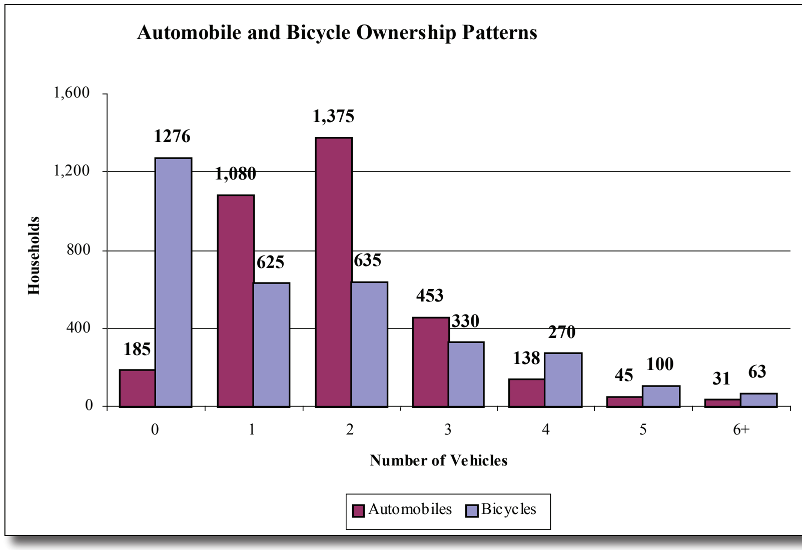



**Figure 17: Automobile and Bicycle Ownership Patterns**

The majority of survey households fall into the largest income category. The typical survey household owns 1.9 automobiles and 1.6 bicycles, and has a household income over $75,000.

## B. Travel Profile

Figures 18 through 21 provide descriptive information on the travel behavior for King County residents who responded to the Puget Sound Household Travel Survey.

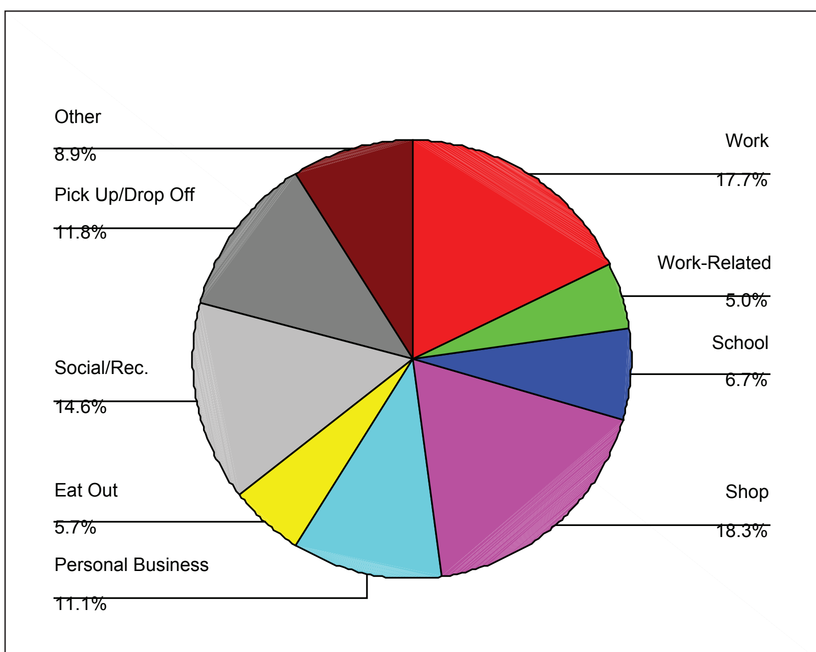



**Figure 18: Trip Purposes**

Work trips accounted for only 18% of the total trips made by King County households, consistent with the findings of the Nationwide Household Travel Survey (NHTS). Non-work trips are shorter in distance and time and occur closer to where we live and work. This suggests that land use mix around places of residence and employment could have a significant impact on modal choice for shorter non-work trips.

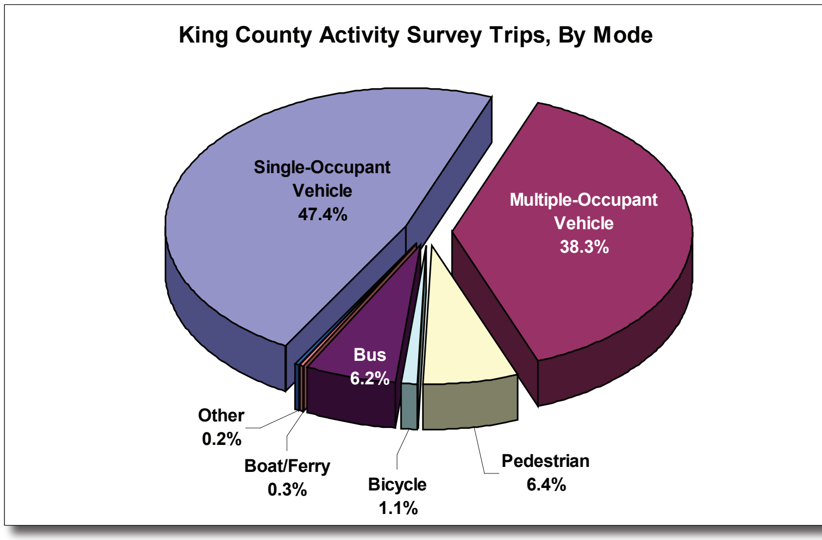



**Figure 19: Mode Shares**

Single-occupant vehicles are the single largest travel mode, followed closely by multi-occupant vehicle trips, including passenger trips, carpools and vanpools.

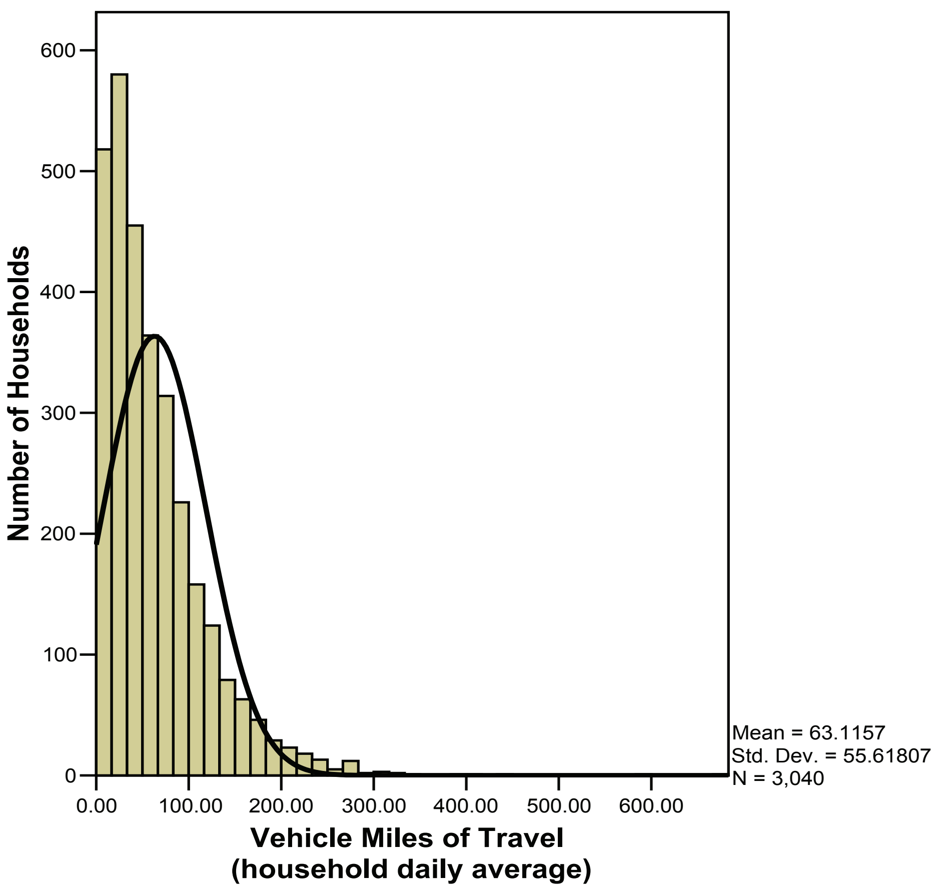



**Figure 20: Household Vehicle Miles of Travel (household, daily average, estimated)**

The average household generated 63 vehicle miles of travel per household, per day, based on estimated travel distances.

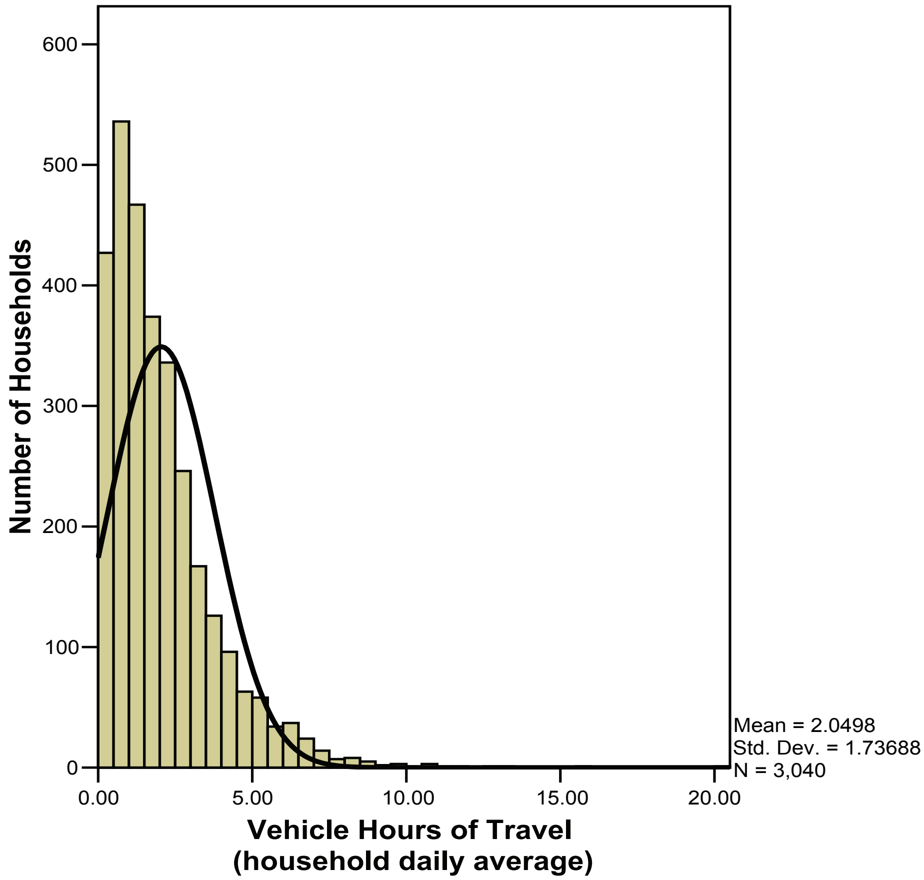



**Figure 21: Household Vehicle Hours of Travel, (daily average, estimated)**

The average household generated two hours of vehicle travel[4] on an average day, based on estimated travel times.

## V. Measuring Health and Urban Form Relationships

Two surveys noted above provided significant information on attributes of public health, including measures of physical activity, weight, and health status. Observations drawn from the Neighborhood Quality of Life (NQLS) and the Silver Sneakers (SS) studies were geocoded, and using the methods outlined in previous sections, buffers were developed around these households and land use and transportation network measures were calculated. A 'network to crow fly' ratio was used to measure the directness of the street network in the household buffer, in order to calculate how easily activities within the community can be accessed from the household. A "gridiron" street network pattern will provide access to a larger area of the surrounding community than a system of cul-de-sacs and collectors, and should increase the likelihood that services and other destinations are within walking distance of a household.

4 Vehicle travel does not include travel by the following modes provided by survey participants walking, bicycle, ferry, other, don't know.

The 16 NQLS communities were selected based on their level of walkability and income as shown in Figure 8 (p. 58). Four communities were selected within each of four walkability and income quadrants. For example, Queen Anne is a high walkability and high income community, whereas Sammamish is low walkability and high income community. Seventy-five participants between ages 20 and 65 were recruited from each community. The basic descriptive characteristics of the NQLS participants shown below in Figures 22-28 are provided courtesy of the NQLS Team as presented by Kelli Glass, NQLS Project Manager, in a peer-reviewed panel at the Society of Behavioral Medicine Conference, March 2004.

## A. Socio Demographic Data

The four high walkability and high income (socioeconomic status, or SES) communities reported the highest percentage of White and educational attainment, as shown in Figure 22 and Figure 23.

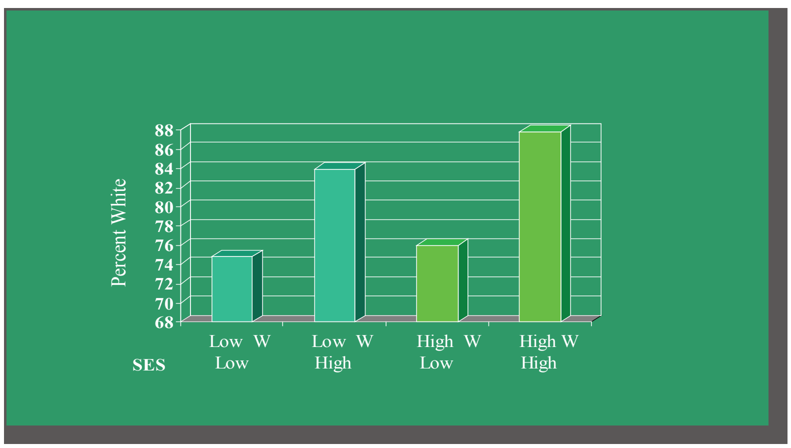



**Figure 22: NQLS Ethnicity (W = Walkability)**

Source: NQLS

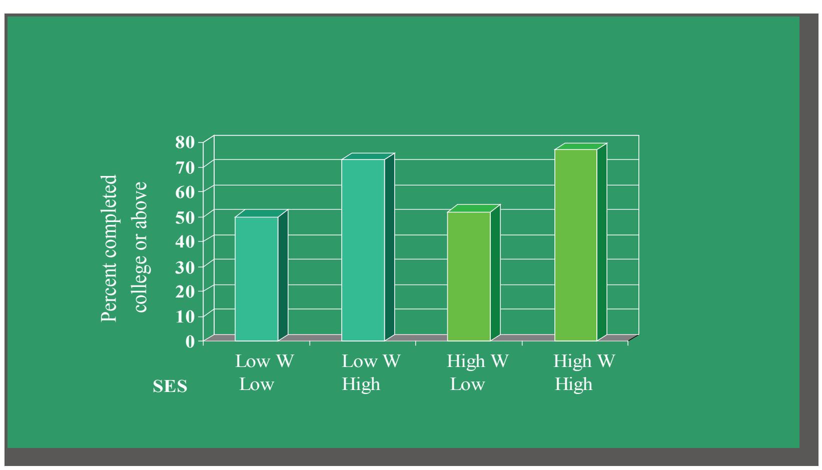



**Figure 23: NQLS Educational Attainment (W=Walkability)**

Source: NQLS

## B. Self Reported Physical Activity and Urban Form

Figure 24 shows that walkability, an index measure of land use mix, density, street connectivity, and floor area ratio of retail, is associated with more walking for transport within both lower and higher SES communities.

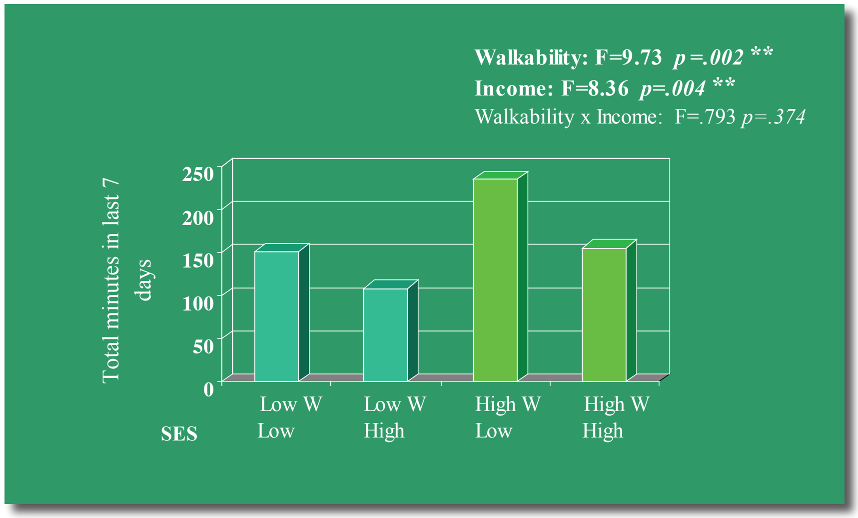



**Figure 24: NQLS Self Reported Minutes of Walking for Transport (W=Walkability) Source: NQLS**

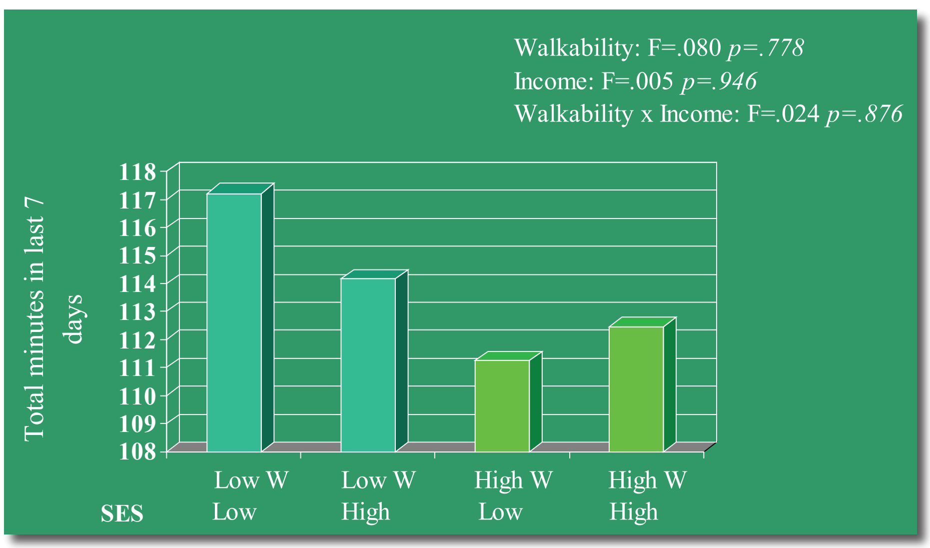



**Figure 25: NQLS Self Reported Walking (W=Walkability) Source: NQLS**

Figure 25 shows that respondents from the lower SES communities reported that they walk more than high SES communities, regardless of each community's level of walkability.

## C. Objectively Measured Physical Activity and Urban Form

Higher walkability was associated with slightly increased moderate and vigorous physical activity for higher but not lower SES communities, as shown in Figure 26 and Figure 27 below.

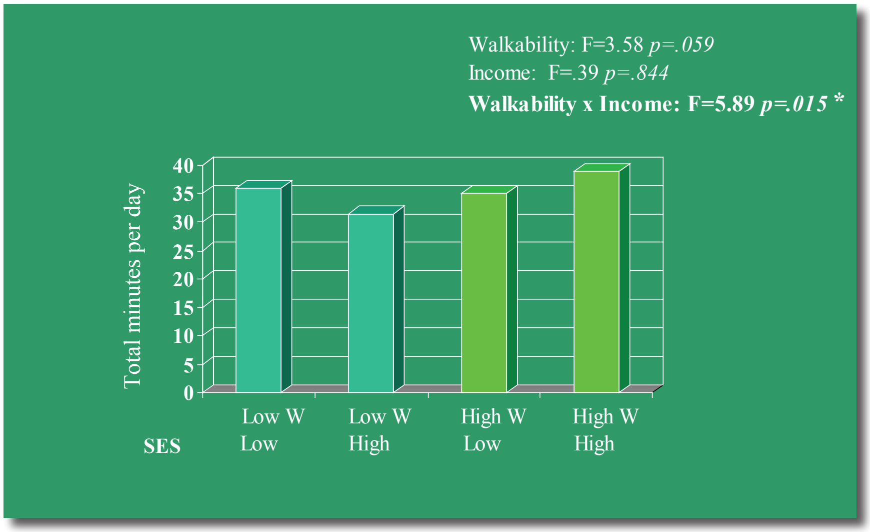



**Figure 26: NQLS Objectively Moderate + Vigorous Activity (W=Walkability) Source: NQLS**

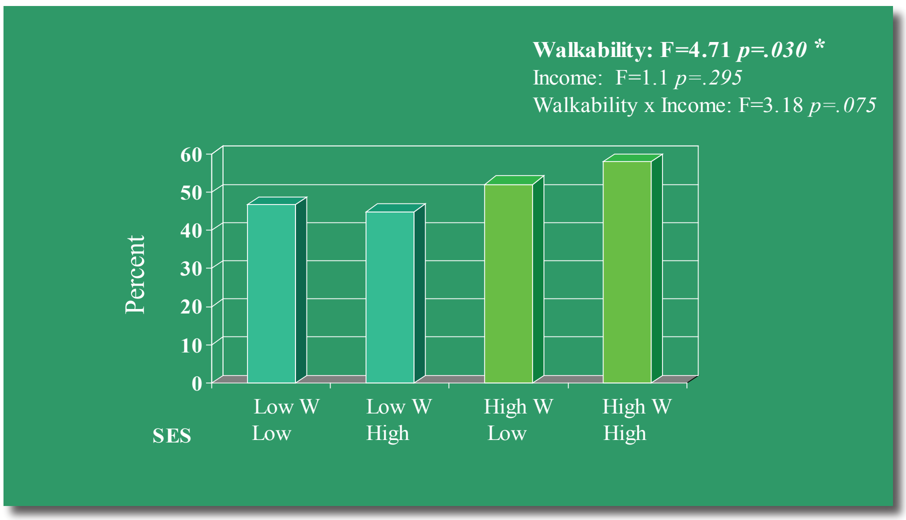



**Figure 27: NQLS Percent Meeting 30 minutes of Moderate Activity (W=Walkability)**

Source: NQLS

Increased walkability was associated with increased proportion of participants who meet the recommended 30 minutes of moderate activity per day. As shown in Figure 28 below, Body Mass Index (BMI) is lower in the more walkable communities for both high and low SES. BMI is higher in the lower SES communities and reaches an alarming mean of 27.5.

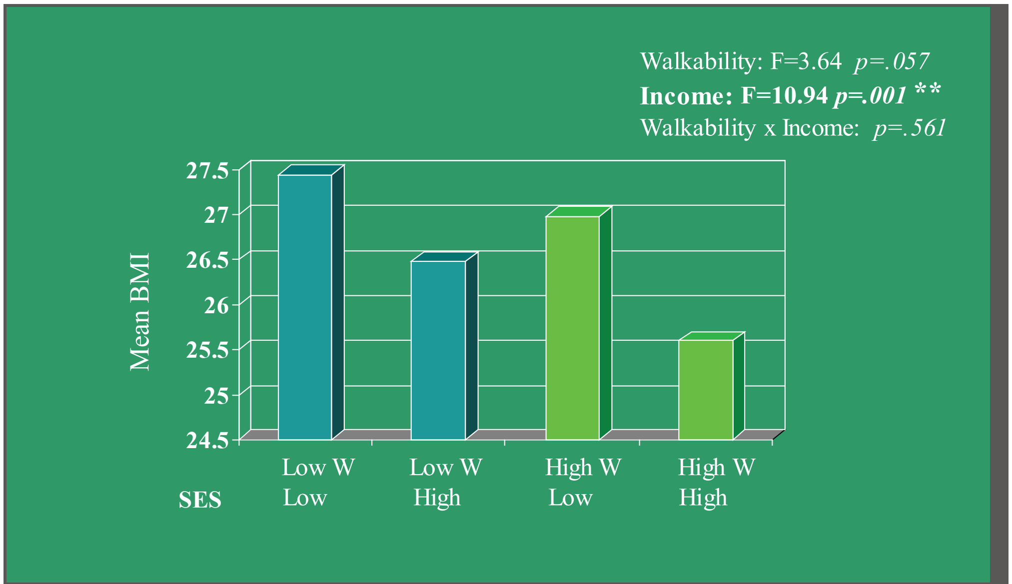



**Figure 28: NQLS Body Mass Index (BMI) (W=Walkability) Source: NQLS**

LUTAQH also analyzed data from the Silver Sneakers Survey conducted by Group Health Cooperative. Participants in this survey were all over the age of 65, Medicaid recipients, and members of the Group Health Cooperative. There are 617 valid Silver Sneaker participants within King County in the Silver Sneakers database. Forty eight percent had an income under $30,000 per year and 61 percent were female. Information on the analysis of the Silver Sneakers database is provided in Chapter IV.

## VI. Measuring Vehicle Emissions of GHGs and Criteria Air Contaminants

Criteria air contaminant (CAC) analysis focused on volatile organic compounds (VOC) and oxides of nitrogen ($NO_x$) emissions (the primary precursors of ground level ozone) and carbon monoxide (CO) emissions because the Seattle-Tacoma area has been designated an ozone and carbon monoxide attainment area by the EPA. The Central Puget Sound Region is a maintenance area for ozone. More recently, the Central Puget Sound Region was also designated as an attainment area for particulate matter (PM-10 micron) (designated May 14, 2001). This research does not address PM-10 micron, however, future research should consider the role of urban form and travel and their impact on particulate matter, and perhaps most specifically, on the formation of harmful 2.5 micron particulate matter.

The 1999 Puget Sound Regional Household Activity Survey includes 101,766 trips with origin and destination coordinates, a trip purpose, travel mode, reported trip distance, and trip start and end times. Following the calculation of greenhouse gas (GHG) and CAC emissions for each trip, analyses were performed to identify relationships between total trip and sub-trip characteristics and pollutant concentrations. Additionally, trip emissions were summed for each person's and household's two days of travel, and the relationship of these aggregate emissions to land uses and the urban form in household and employment buffers were identified. A brief outline of the key methods and assumptions used to calculate GHG and CAC emissions is provided here. All calculations were conducted using the most current US Environmental Protection Agency (EPA) emissions modelling software, MOBILE 6.2, as well as the Puget Sound Regional Travel Demand Forecasting Model based upon EMME/2.

## A. Trip Path Calculation Process used in GHG & CAC Emissions Estimation

Trip attributes reported in the Activity Survey included the travel mode, trip origin and destination, trip start and end time, and estimated distance traveled. Since actual trip paths were not recorded in the Household Activity Survey, trip speed and distance by facility type were estimated in a Geographic Information Systems (GIS) environment. In order to create the sub-trip characteristics, trips reported in the 1999 Household Activity Survey were converted to trip files with origin and destination coordinates. The loaded Puget Sound Travel Demand Forecasting Model was used in this process as follows:

1. The distance from the origin to the closest point on the regional road network was determined and stored;

2. The distance from the destination to the closest point on the road network was determined and stored;

3. These two estimated distances were used to approximate the proportion of local road travel in the total trip;

4. The shortest trip time path was estimated from the origin to the destination using link travel times (AM Peak, PM Peak, or Off-Peak, as determined by the reported trip start time);

5. The traversed links were stored along with the road facility type and estimated average speed.

This process was repeated for the 101,766 trips in the four county Household Activity Survey database. Figure 29 graphically depicts the sequencing of consecutive trips links to estimate a trip path for a trip reported in the survey.

Successful estimation of the trip paths in the regional travel model required two main assumptions. First, the estimated path represents the shortest travel time path for the estimated congestion conditions represented in the loaded model network. The actual travel path followed by the survey respondent may be quite different. This may not be as important as it at first seems, because the purpose of the network algorithm used in the travel model was to identify the proportions of trips that occur on arterials and freeways, and their associated speeds based on the time of day in which the trip occurred. While the respondent's reported time is a better indicator of the actual travel time than the estimated path time, the path estimated by the model is representative of speeds by facility type.

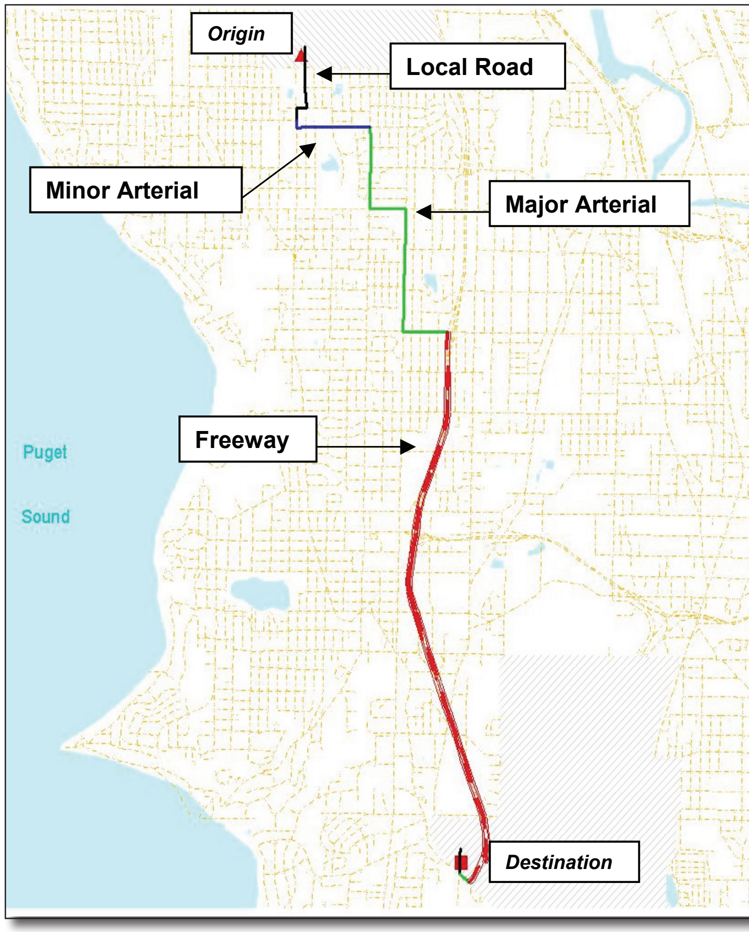
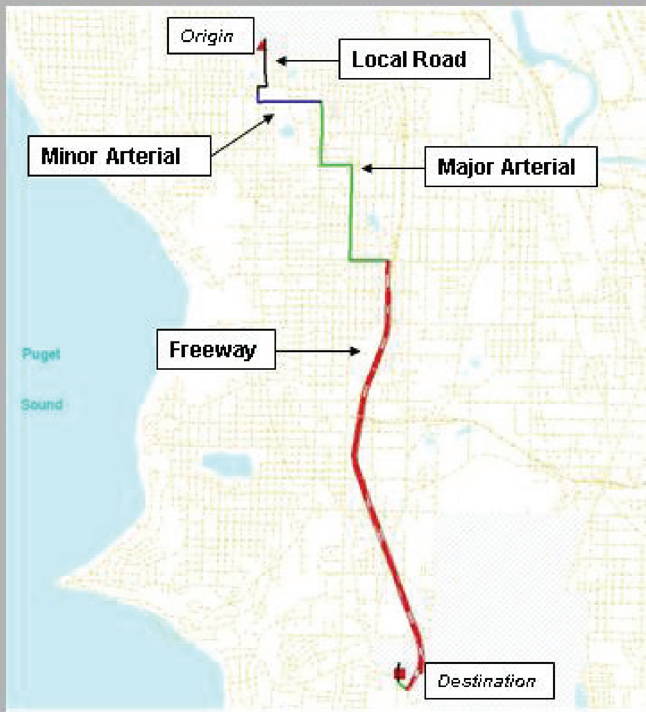



**Figure 29: Illustration of the Sequencing of Consecutive Trips**

Source: Frank et al 2003b

The second assumption concerns the way in which distances and speeds were calculated for travel on local roads. Since local roads are not represented in the Travel Demand Forecasting model networks, Euclidean distances at an average speed of 15 mph were used. It is reasonable to assume that local road travel is slightly faster than 15 mph, and in fact Mobile 6.2 assumes that local road travel is closer to an average of 22 mph. The slower speed used in this application is designed to account for the fact that the local road path is not as direct as Euclidean travel. Figure 30 illustrates the way in which household emissions are calculated for each segment of the trip characterized by a change in facility type or speed.

**Methodology to Estimate Household Emissions**




| Facility Type | Distance | AM Peak Speed | Emission Estimates |
|---|---|---|---|
| | (miles) | (mph) | |
| Local Road | 0.8 | 20 | *Using EPA sanctioned models, gram per mile emissions of HC, CO, NOx, and PM will be calculated.* |
| Minor Arterial | 0.5 | 25 | |
| Major Arterial | 4 | 35 | |
| Freeway | 7.5 | 55 | |
| **Total** | **12.8** | | |

***The model speed will be used based on the facility type instead of assuming an average trip speed.***

**Figure 30: Calculations for Household Emissions According to Facility Type or Speed**

## (1) Modal Adjustments Based On Special Conditions

### *(a) Auto and Light Truck*

Vehicle occupancy is an important consideration in analysis of emissions by all modes. For light duty automobiles, vehicle occupancy was calculated based upon trip attributes reported in the Household Activity Survey, including:

- Number of household members on the trip;
- Unique identifiers for the particular household members on the trip; and
- Total number of persons (household and non-household) on the trip.

For automobile and light duty truck trips, the emissions for each trip were assigned to the survey respondent (driver or passenger) in terms of their vehicle occupancy percentage based on the number of persons on the trip. Thus, the trip emissions were divided by vehicle occupancy to calculate the per person trip emissions. For example, if a carpool trip consists of two household members, person

"A" and person "B," in which person "A" takes person "B" to work and then continues on to his / her employment site, person "A" would be assigned 50% of the trip emissions. Similarly, person "B" would be assigned the other 50% of the trip's emissions.

If the carpool consists of three persons, "A," "B," and "C," in which "A" and "B" are members of the same household and "C" is neither a household member nor a survey participant, persons "A" and "B" would each be assigned 33% of the trip emissions. The non-survey respondent's (person "C") portion of emissions would not be included in the analysis as these emissions skew the trip level vehicle emissions and cannot be traced to an origin residence or employment destination.

Subtracting the number of household member person identifiers recorded for the trip from the total reported number of household members on the trip helped identify if children who were household members but not survey participants were along for the ride. (A child under the age of ten would not have a person identifier but would be included in the total number of household members on the trip.) If children under age ten were present, their number was subtracted from the total reported household members in the vehicle for calculating of vehicle occupancy.

*(b) Bus*

Bus trips include school bus and transit trips. Accurate calculation of emissions for these trips suffers from assumptions of occupancy and static speed. Occupancy rates for school and transit buses were assumed to be 20 persons in off-peak conditions and 50 during peak periods. Emissions for bus trips were estimated using the portion of the trip that occurred on the bus, divided by the occupancy rate. For the calculation of these emissions, it was assumed that any local road travel occurred outside of the bus. In other words, bus trips were assumed only to take place on arterial and freeway trip links.

*(c) Motorcycle/Moped*

Motorcycles were modeled exactly like light-duty automobiles. Using Mobile 6.2, the ratio of the average gram / mile emissions rates for motorcycles as compared with the average light duty auto was used to create a 60 percent factor for the calculation of motorcycle emissions. It was also assumed that motorcycle trips had an occupancy rate of one driver.

*(d) Non-motorized*

Walk and bicycle modes were assigned zero emissions.

*(e) Carpool*

Carpools were assumed to have an average occupancy rate of 2.2.

#### *(f) Vanpool*

Vanpools were assumed to have an occupancy rate of 7 persons per van. Trip emissions were factored by these rates to reflect the per person trip emissions.

#### *(g) Taxi/Limousine*

Emissions created by taxi and limousine trips were increased by 50% to account for the extra distance required for pickup and return. Vehicle occupancy was calculated in the same manner as other light duty automobiles.

#### *(h) Trips with an External End*

Trips that have one or both ends outside of the model road network area, but had both origin and destination located within Washington State, were handled in a separate manner. If the trip was 5 minutes or shorter, it was assumed that the person traveled on local roads only. For trips less than 15 minutes, ten minutes of travel were assigned to arterials and five minutes to local roads. Any portion of a trip outside the study area and greater than 15 minutes in duration was assigned to freeway travel. These factors were defined from brief analysis of long trips within the study area.

## B. Special Considerations in the Estimation of GHG Emissions

In order to estimate GHG emissions associated with trips reported for King County households in the survey, it was necessary to develop a methodology to break trips into their sub-component parts. The approach used expands upon existing techniques by creating an estimated trip path in a Geographic Information Systems (GIS) environment based on the regional travel demand model road network. The estimated trip path was delineated into sub-components, according to time and distance traveled on different road facility types, in order to allow for the detailed calculation of emission rates based on the type of road and peak or off-peak travel speed. This refinement of trip level emissions modeling is a significant advancement, because it means that trips reported to have the same travel time in the household activity survey can be modeled differently to reflect their actual trip characteristics. Typically, in trip emissions modeling an average speed is applied for the duration of the trip in order to calculate emissions; however, it is reasonable to assume that the same reported travel time for two different trips could result in very different levels of emissions, depending on the road used during the trip path – for example where one is a shorter distance trip traveling at slower speeds on congested arterials, and the other is a longer distance trip traveling at higher speeds on a freeway.

### 1. Calculation of GHG Emission Rates for $CO_2$, $N_20$, and $CH_4$.

After the regional travel model recorded the sub-trip characteristics, including the distance and speed for each facility type traversed, carbon dioxide ($CO_2$), nitrous oxide ($N_2O$), and methane ($CH_4$) emission factors were applied to freeway and arterial travel for each mode based on the distance traveled to calculate trip level GHG emissions. The distance traveled on local roads was added to the distance traveled on arterial roads since $CO_2$ rates do not currently exist for local road travel. These values were summed to produce total trip emissions for each of the three GHGs. Trip duration and distance traveled on freeway, arterial, and local roads were also calculated for each trip.

## C. Special Considerations in the Calculation of CAC's

As with the calculation of GHG emissions, trip level Criteria Air Contaminant (CAC) emissions were calculated by first estimating emissions for individual trip links, then summing these emissions for the entire trip path. However, in the case of CACs, the approach included the separate modeling of engine start emissions and running exhaust emissions.

The general process of analysis is shown in Figure 31. Household Activity Travel Survey data, Puget Sound programmatic and atmospheric variables, and the Puget Sound loaded travel demand forecasted model were used as inputs into the process. These elements were first used to estimate a trip path for each of the trips in the survey, as well as pre-trip engine soak time, based on the reported interval between vehicle trips. Next, emissions were estimated for individual trip links, which were then aggregated to the trip, person, and household levels. Assumptions and treatment of special cases are described in more detail in the text below.

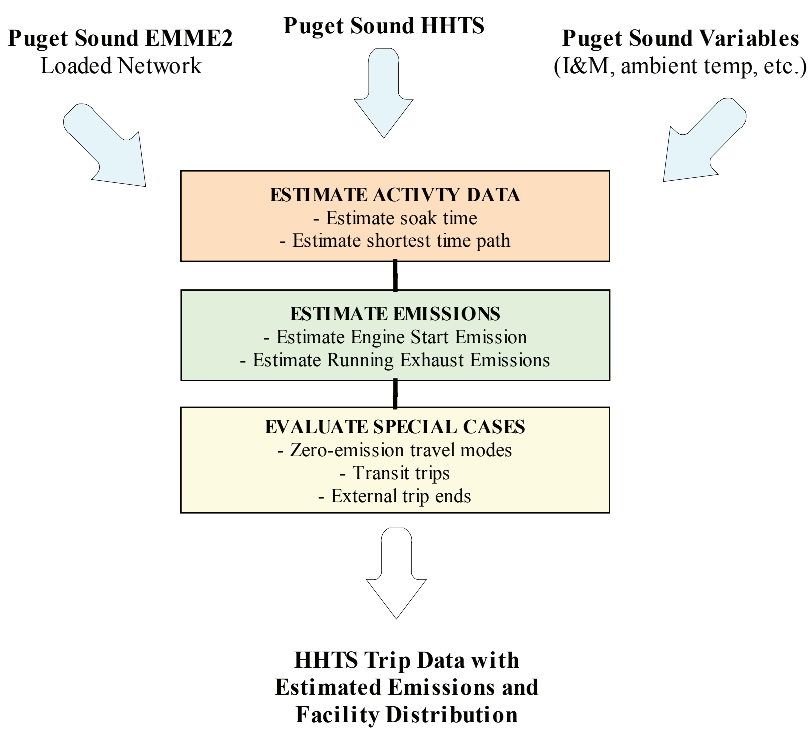



**Figure 31: Process of Calculating CAC's**

Source: Frank et al 2003b

## 1. Trip Activity and Emissions Estimation

Trip activity refers to the mode, path, speed and travel time for the reported trip. Information reported in the household activity survey was used as much as possible to define the emission-specific characteristics of the trip.

### a) Engine Start Activity (Soak Time)

The amount of time that a vehicle is at rest with the engine off – its soak time -- is an important factor in estimating the extent of elevated emissions that occur during the beginning of a trip. A vehicle that has cooled off significantly will require a longer period of time before its engine temperature reaches a point when on-board emissions control equipment can operate efficiently. Shorter engine-off periods (warm starts) do not require as much time to reach an efficient level of emissions control. Estimating the amount of soak time is simply a matter of determining the amount of time between trips. MOBILE 6.2 allows for 70 different ranges of engine soak time (e.g., 1-2 minutes, 30-35 minutes) to be used in calculating emissions in the period of a trip before the engine has warmed up sufficiently to control emissions at top efficiency.[5]

### b) Running Exhaust Activity

Running exhaust activity refers to that portion of a vehicle trip when hot-stabilized emissions are produced. MOBILE 6.2 allows users to separately calculate emissions for different road facility types (local, arterial, ramp, and freeway) at five mile per hour speed increments, a useful feature given that driving characteristics (especially acceleration rates) vary sufficiently enough amongst the different facility types to warrant different baseline emission rates (for example, a vehicle traveling at an average speed of 45 on an arterial will produce a different emissions profile than a vehicle traveling at an average speed of 45 on a freeway). This capability can help to evaluate the differences in trip emissions for two different trips that have similar travel times but different travel distances. In addition, this also enables us to assess differences in emissions based on the proportion of trip by facility type while accounting for facility performance or "congested flows." Further details on the modeling of hot-stabilized emissions can be found in the CAC background report.

Emission factors estimated using MOBILE 6.2 were applied to the separately calculated trip path components and then summed in order to generate grams of CO, VOC, NOx, and $CO_2$ for each unique trip.

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5 Note that $CO_2$ is not elevated during engine start conditions and does not vary significantly by soak time.

### 2. Methodological Assumptions about CAC Emissions Estimation

In both engine starts and running exhaust emissions modeling, assumptions were made regarding the operating conditions and the vehicle age. The model was run assuming that the trips were conducted in July 1999, that an inspection and maintenance program was being conducted using an IM240 test for odd model year vehicles, and that a default national model year distribution represents Seattle distributions.

### 3. Mode Specific Emissions Adjustments

#### a) Buses

No engine start emissions were assigned to the individual trips. Bus trips also assumed that any estimated local road travel occurred outside of the bus during a trip chain; bus trips, therefore, only included arterial and freeway trip links.

#### b) Motorcycles

Motorcycles were modeled exactly like light-duty automobiles except that separate emission factor lookup tables were generated and used.

## VII. Conclusion

The methods used in this study represent one of the first times that multiple measures of fine grained, parcel level land use has been linked together with detailed physical activity and trip diary data for analysis of land use – travel behavior relationships. In addition, the GHG and CAC emissions methods allow for the detailed modeling of trip emissions at the network link level, allowing for detailed analysis of the relationship between household emissions and land uses near to home and work locations. These methods allow for analysis of these relationships at a unique level of detail, and as the discussion of regional level travel behavior – land use relationships in the following chapter will show, they enable the development of predictive models which will be of value to planners wishing to ground their land use and transportation policy guidance in empirical evidence.

# Chapter IV: Relationships Between Urban Form, Activity Patterns, Air Quality, and Health—Regional Assessment

## I. Overview

This chapter presents a broad array of research linking urban form with behavioral outcomes, and extends these linkages to air quality, greenhouse gas formation, and human health. It builds upon the policy framework presented in Chapter I, emerging issues presented in Chapter II, and database development approaches documented in Chapter III. The research presented in this chapter is unique, both in terms of the level of detail provided about specific findings and the breadth of issues that are covered. Research is presented on urban form relationships with walking, transit, vehicle use, vehicle emissions, greenhouse gas formation, and physical activity.

## II. Walking

This study seeks to measure the effects of land use patterns at the household location on walking trip rates, for a better understanding of how changes in land use configurations around household locations can be used to encourage travelers to switch from private automobiles and other modes to walking. The potential to change travel patterns in King County is enormous — 42 percent of trips in the county are three miles or less, mostly distances easily traveled on foot or bicycle. Yet of the 16 percent of trips that are less than one mile, 43 percent are currently made by automobile drivers.

### A. Walker Characteristics and Walking Trip Purposes

Data from the Puget Sound Household Activity survey was used to evaluate the relationships between urban form and walking for both recreational and utilitarian purposes. In a sample of 7,548 respondents slightly more than 10 percent (842 respondents) reported at least one walking trip in the two-day period. Among all respondents, 2.5 percent reported walking to work, and 9 percent reported walking as their mode of choice for travel to school. Overall, 4.5 percent of all trips reported by King County residents were on foot. Trip purposes are described in Table 4.

| Trip Purpose | Percent of Trips |
|---|---|
| Social/recreational | 19.5 |
| To work | 18.0 |
| To school (K-12) and daycare | 17.0 |
| Incidental shopping (errands) | 10.3 |
| Accessing services | 9.9 |
| Personal business | 9.7 |
| Pick-up/drop-off from school | 6.0 |
| Other purposes* | 9.4 |

**Table 4: Walking Trip Purposes**

Trips classified as *home* and c*hange mode* have been Excluded

(* Other contains all purposes that individually account for less than 5 percent of total walk trips)

Very low walk rates are reported. Similar to the recently collected Atlanta based SMARTRAQ survey, over 90 percent of participants reported no walking at all. However, every trip begins on foot, and walk trips are, no doubt, under-reported in the survey. The walk trips that were reported were somewhat evenly distributed across purpose. Six different purposes had at least 9 percent of the reported walk trips. Walking is reported as both a recreational and a utilitarian activity -- to accomplish goals such as travelling to work and to school and for completing everyday personal activities. Clearly, for a subset of respondents walking is an important travel mode for accomplishing daily activities.

Compared to all respondents from the King County travel survey, frequent walkers[1] are more evenly distributed across gender, but are representative of the larger survey's ethnic distribution (see Table 5 and Table 6 below). A larger percentage of walkers in the survey have less than or only a high school education (see Table 7) which corresponds to a higher proportion of youth who walk to school in the "frequent walker" sub-set. However, higher educational attainment was also found to be associated with increased walking, indicating somewhat of a bi-modal distribution – walkers are either young or older and perhaps more educated (see Table 8). A similar difference is seen between the frequent walker subset and the regional sample on age (see Table 9 and Table 10). Eliminating people reporting travel to school increases the median age for the frequent walker sample to 42, and the regional sample to 46. The fact that frequent walkers are younger on average than King County survey respondents in general (not including those walking to school) is not surprising given that younger people are generally more active than older. Income distribution, the number of household vehicles and household size are quite similar to regional averages (see Table 11 through Table 13).

| Gender | King County | Walkers | Walker Difference |
|---|---|---|---|
| Male | 48% | 50% | +2% |
| Female | 51% | 50% | -1% |

**Table 5: Gender of Frequent Walkers Compared with King County Survey Respondents**

1 This study defines frequent walkers as those who take more than 2 walking trips per day (n= 349).

| Ethnicity | King County | Walkers | Walker Difference |
|---|---|---|---|
| White/Non-Hispanic | 93% | 92% | -1% |
| Hispanic/Latino | 2% | 1% | -1% |
| African American | 1% | 2% | +1% |
| Asian/Pacific Islander | 3% | 3% | 0% |
| Native American | 1% | 1% | 0% |
| Other | 1% | 1% | 0% |

**Table 6: Ethnicity of Frequent Walkers Compared with King County Survey Respondents**

| Educational Attainment | King County | Walkers | Walker Difference |
|---|---|---|---|
| Less than High School | 25% | 43% | +18% |
| High School | 16% | 11% | -5% |
| Some College | 19% | 11% | -8% |
| Technical/Vocational | 4% | 2% | -2% |
| Undergraduate/Bachelors | 21% | 19% | -2% |
| Graduate/Post-Graduate | 15% | 14% | -1% |

**Table 7: Educational Attainment of All Frequent Walkers Compared with King County Survey Respondents**

| Education Not in K-12 | King County | Walkers | Walker Difference |
|---|---|---|---|
| Less than High School | 7% | 8% | +1% |
| High School | 20% | 18% | -2% |
| Some College | 23% | 17% | -6% |
| Technical/Vocational | 4% | 3% | -1% |
| Undergraduate/Bachelors | 26% | 31% | +5% |
| Graduate/Post-Graduate | 19% | 24% | +5% |

**Table 8: Educational Attainment of Frequent Walkers not in K-12 Compared with King County Survey Respondents**

| Age –whole sample | King County | Walkers | Walker Difference |
|---|---|---|---|
| Mean Age | 38.5 | 29.1 | -9.4 |
| Std. Dev | 21.7 | 20.4 | -1.3 |

**Table 9: Age of All Frequent Walkers Compared to King County Residents**

| Age – not in K-12 | King County | Walkers | Walker Difference |
|---|---|---|---|
| Mean Age | 46.3 | 41.9 | -4.4 |
| Std. Dev | 18.1 | 17.5 | -0.6 |

**Table 10: Age of Frequent Walkers out of School Compared to King County Residents**

| Household Income | King County | Walkers | Walker Difference |
|---|---|---|---|
| Less than $10,000 | 1% | 2% | +1% |
| $10,000 to $14,999 | 1% | 1% | 0% |
| $15,000 to $24,999 | 5% | 5% | 0% |
| $25,000 to $34,999 | 7% | 5% | -2% |
| $35,000 to $44,999 | 14% | 13% | -1% |
| $45,000 to $54,999 | 15% | 16% | +1% |
| $55,000 to $74,999 | 24% | 26% | +2% |
| $75,000 and Greater | 33% | 32% | -1% |

**Table 11: Household Income of Frequent Walkers Compared with King County Survey Respondents**

| Household Vehicles | King County | Walkers | Walker Difference |
|---|---|---|---|
| Mean Vehicles | 2.1 | 2.2 | +0.1 |
| Std. Dev | 1.1 | 1.0 | -0.1 |

**Table 12: Household Vehicles of Frequent Walkers Compared to King County Residents**

| Household Size | King County | Walkers | Walker Difference |
|---|---|---|---|
| Mean Size | 3 | 3 | 0.0 |
| Std. Dev | 1.4 | 1.3 | -0.1 |

**Table 13: Household Size of Frequent Walkers Compared to King County Residents**

These results indicate that, outside of age and education differences, frequent walkers are quite similar to regional respondents in general. The next section of the study seeks to determine if land use near the household can help to further explain differences in household walking trip rates.

## B. Correlation Results

### 1. Walking and Land Uses

Preliminary correlations were developed between walk trips and each of the three measures for individual land uses – number of attractions (uses), rentable building area and total parcel area – to identify which measure was best correlated with walking trips. Table 14 shows the Pearson's R coefficients, along with their statistical significance (P value) in parentheses, for the correlation of the three measures of each land use with walking, when controlling for household size and income.

| Land Use Type | Number of Attractions | Rentable Building Area | Total Parcel Area |
|---|---|---|---|
| *Civic* | 0.2503 (P=0.000) | 0.1025 (P=0.000) | 0.0786 (P=0.016) |
| *Convenience Stores* | 0.116 (P=0.000) | 0.1031 (P=0.000) | 0.0303 (P=0.110) |
| *Doctor-Dentist Offices* | 0.1585 (P=0.000) | 0.1985 (P=0.000) | 0.0649(P=0.001) |
| *Educational* | 0.2706 (P=0.000) | 0.1572 (P=0.0294) | 0.1473 (P=0.000) |
| *Entertainment* | 0.1994 (P=0.000) | 0.0294 (P=0.000) | 0.0093 (P =0.624) |
| *Fast Food Restuarants* | 0.0932 (P=0.000) | 0.0825 (P=0.000) | 0.0455 (P=0.016) |
| *Grocery Stores* | 0.2512 (P=0.000) | 0.1771 (P=0.000) | 0.1174 (P=0.000) |
| *High-Tech Industry* | -0.0064 (P=0.735) | -0.0149 (P=0.431) | -0.0154 (P=0.415) |
| *Museums* | 0.134 (P=0.000) | 0.1571 (P=0.000) | 0.0857 (P=0.000) |
| *Office Buildings* | 0.3277 (P=0.000) | 0.1727 (P=0.000) | 0.2243 (P=0.016) |
| *Office Parks* | 0.0056 (P=0.767) | -0.0016 (P=0.932) | 0.0022 (P=0.907) |
| *Office - Miscellaneous* | 0.1081 (P=0.000) | 0.1068 (P=0.000) | 0.1104 (P=0.000) |
| *Parks* | 0.1497 (P=0.000) | NA | 0.0287 (P=0.130) |
| *Playgrounds* | 0.0784 (P=0.000) | NA | 0.021 (P=0.267) |
| *Recreational* | -0.0050 (P=0.790) | -0.0159 (P=0.402) | 0.0134 (P=0.478) |
| *Restuarants and Taverns* | 0.3176 (P=0.000) | 0.2882 (P=0.000) | 0.1573 (P=0.000) |
| *Retail - Large* | 0.2069 (P=0.000) | 0.1468 (P=0.148) | 0.0371 (P=0.050) |
| *Retail - Neighborhood* | 0.3806 (P=0.000) | 0.3287 (P=0.000) | 0.1958 (P=0.000) |
| *Vacant Parcels* | -0.0394 (P=0.037) | NA | 0.0021 (P=0.912) |

**Table 14: Correlations between Land Use and % Household Walk Trips (Controlling for Household Size and Income)**

The land uses most strongly correlated with the percentage of household walk trips proved to be educational facilities, commercial office buildings, restaurants and taverns, and neighborhood-scale retail establishments, with civic uses and grocery stores following closely. These findings are as one would expect. Having establishments such as these within a quarter-mile of one's place of residence allows individuals to accomplish major trip purposes, such as work and shopping trips, by walking. Of the 17 land uses measured, only high-tech industrial uses and office parks failed to have statistically significant correlations with walking rates along any of the three land use measurement categories.

### a) Walking and the Number of Unique Attractions

As noted earlier, the research team hypothesized that rentable building area would be the land use measure to show the strongest correlation with household walking trip rates. Interestingly, however, the sheer number of attractions by use, rather than their rentable building area, consistently proved to be the more significant variable in understanding walk trips. What these findings suggest is that the number of meaningful attractions within a quarter-mile of one's home may be more important than the size or quality of the attraction itself in the decision to walk. These are indeed strong correlations and beg the question:

> "Will increasing the number of commercial destinations in residential communities result in increased physical activity and reduced air pollution and obesity and other adverse impacts of driving?"

When one considers the role that self-selection may play in determining walk trips, these results appear to make sense. This argument would follow that individuals who are predisposed to walk, choose to live in environments with more destinations accessible on foot. Individuals who choose to live in neighborhoods that are walkable have automatically self-selected themselves to neighborhoods with multiple *destinations* that are within walking distance of their household as well. Those neighborhoods with more unique destinations within walking distance of a household appear to be more desirable to these individuals because of the increased number of destination options they provide for walking – a greater number of unique attractions in the local neighborhood provide the ability to select the destination attraction that best suits the trip purpose. If this is the case, then the variety of land uses in these neighborhoods are only in part motivating people to walk more; that is, people who like to walk are moving to (or staying in) these neighborhoods, if they are available and affordable. The latter part of the last sentence is the key; emerging research suggests that many residents of auto oriented environments would prefer an environment with walkable destinations, but have traded it off because it is undersupplied, and this undersupply has driven the cost up to the point where locating there is economically illogical, or even infeasible (Levine et al 2003; Levine and Frank 2004).

While this existing data does not provide information on the location decision of households, and consequently cannot confirm or deny this hypothesis, it would seem that if the concept of locational self-selection is indeed valid, then individuals would be willing to sacrifice larger homes to be in an area that had multiple, complementary destinations. Unfortunately, the economics of this trade-off often result in opting out of walkability for a larger home further out. The current system provides the ability to externalize much of the transportation, land development, and environmental costs associated with an outlying area where consumers can get a larger house for less money. Finally, there are several emerging studies that are beginning to show that both preferences and built environments impact behaviour. This new research suggests that whether or not one prefers to walk or take transit; or prefers walkable or auto-oriented communities, people are less auto-dependent if the built environment makes it rational to choose walking and transit for at least part of daily travel. Whether or not self-selection is responsible for the number of attractions being most strongly correlated with the percentage of walk trips, it is clear that having multiple destinations near one's house better explains incidences of walking than gross parcel area or the rentable building area. For some uses, such as restaurants, this makes sense. Multiple small restaurants provide a greater variety of dining options than do several larger restaurants, which may be able to serve a greater number of people but which provide for fewer dining options. Rentable space or square footage also matters, but often to a lesser extent. More commercial office space translates into the number of jobs that can be housed within it. More square feet means more job opportunities, which consequently increase opportunities for walk trips, regardless of the numbers of different office buildings available.

#### b) Walking and Rentable Square Footage

While the strong correlations found between the percentage of walking trips per household and the total number of attractions would seem to indicate that having more attractions in a neighborhood is better, regardless of the actual square footage of usable floor area, it is important to recognize that the aggregate number of attractions of a particular land use type bears no relationship to the actual ability of these attractions to achieve desirable household travel destinations. For establishments such as retail and commercial office space, one would expect that the total square feet of space dedicated to each use would increase the percentage of walk trips, because more commercial square footage translates to more jobs, and more retail square footage translates to more product options.

To illustrate using Wal-Mart as an example (and ignoring the economic and aesthetic impacts that a Wal-Mart may have on a community), a Wal-Mart retail store provides individuals with a full range of retail options at a single location. This single store is equivalent to the square footage in a neighborhood commercial district where the same retail services are distributed amongst a variety of stores. Due to the fact that a large retail chain necessarily seeks to include a complementary host of merchandise in-house, and because centralized merchandise planning occurs for the chain, the variety of merchandise available at a Wal-Mart can easily exceed that of a series of individual, "neighborhood" stores in a neighborhood commercial district. Having a Wal-Mart within a quarter-mile distance of one's home provides an individual with a host of retail options that can readily meet most of their retail shopping needs.

This assumption that "bigger is better" underlies conventional travel modeling, which is based on the theory that the larger the attraction, the greater its "gravitational pull" on potential users. In the case of retail, such "gravity models" assume that more building floor area translates into a stronger attractor for shopping trips. While this concept has certain face validity, the correlation results indicate that the reality may, in fact, be more complex. Big-box stores, despite their size, had much weaker correlations with walking than did smaller, neighborhood-scale retail establishments. Furthermore, given that the number of attractions consistently proved to be more highly correlated with the percentage of household walk trips, this indicates that a fine grain of uses is important to individuals who walk.

However, it is possible that neighborhood factors beyond the quantity of uses themselves may be involved, and our data support this argument as well. In addition to having more, smaller, individual land uses, neighborhoods regarded as being "walkable" typically have other characteristics conducive to walking – network connectivity, sidewalks, street trees, and aesthetic elements such as public art, uniform building setbacks, and integrated cornice lines, to name a few.

#### c) Walking and Parcel Area

Of the three types of land use measures – numbers of attractions, rentable building area, and parcel area, parcel area was the measure that had the weakest correlations with household walk trips. This finding is unsurprising – parcel area has little relationship with the actual building density on a site. Areas with greater building floor area to land area ratios (floor area ration – FAR), or multiple uses on site, provide more destination attractions, and hence more opportunities for household walk trips.

### 2. Walking and Urban Form

To explore the hypothesis that aspects of urban form and neighborhood aesthetics may be responsible for the weak correlations between the rentable floor-area measure and walking, we measured the correlation between urban form itself and the percentage of household walk trips. While the data would not permit us to develop measures for the presence of street trees or other aesthetic treatments, we were able to develop measures for the connectivity of the street network and for the presence of sidewalks. The two measures were as defined as follows:

- ***Street connectivity*** or intersection density refers to the number of intersections per square kilometer of the buffer area. More intersections equates to better route choices for pedestrians, as well as opportunities to follow a "shortest path" to a desired destination attraction. The average survey household has approximately 68 intersections per square kilometer within their buffer area, with connectivity estimates ranging from 0 to 223 intersections per square kilometer.
- ***Sidewalk density*** is the number of parcels with sidewalks, divided by the total number of parcels in the buffer. This measure produces a value ranging from 0 to 1, with one indicating that all parcels have sidewalks, and 0 indicating that no parcels have sidewalks. While this measure does not capture the continuousness of the sidewalk network, is does provide a

gross estimation of the availability of an adequate pedestrian environment. Sidewalks were present on 27 percent of the parcels located in the buffer area around the average survey household.

Levels of street connectivity and sidewalk density varied dramatically across the household buffer areas, strengthening the argument that differences in these design elements may help to explain household walking trips. The research team ran correlations between the two design variables and the percentage of household walk trips to test these relationships. The results are shown in Table 15 below.

| Design Measure | Correlation Coefficient |
|---|---|
| *Street Connectivity* | 0.2354 (P=0.000) |
| *Sidewalk Density* | 0.0674 (P=0.000) |

**Table 15: Correlations between Street Connectivity, Sidewalk Density, and the Percentage of Household Walk Trips**

(Controlling for Household Size and Income)

Both measures had weak to moderate correlations with the percentage of household walk trips, and both relationships were highly significant. While neither of the correlations could be termed "strong," their significance levels support what we had hypothesized: these variables may act as moderators that help explain, in part, the household walking trip rates.

Once these design measures were defined, we could control for their effects to better understand the relationship between walking and land uses as defined by the three measures. We speculated that, when controlling for the influence of street connectivity and sidewalk density on the percentage of household walking trips, the relationships between the rentable floor area of a use and household walking trips would increase, while the relationship between walking and the number of unique destinations would remain constant or, more likely, decline. Table 16 shows the new correlations when controlling for the influence of these design elements.

| Land Use Type | Number of Attractions | Rentable Building Area | Total Parcel Area |
|---|---|---|---|
| *Civic* | 0.2073 (P=0.000) | 0.1683 (P=0.000) | 0.0806 (P=0.000) |
| *Convenience Stores* | 0.1183 (P=0.000) | 0.1060 (P=0.000) | 0.0472 (P=0.000) |
| *Doctor-Dentist Offices* | 0.1394 (P=0.000) | 0.1661 (P=0.000) | 0.0568 (P=0.000) |
| *Educational* | 0.2594 (P=0.000) | 0.1427 (P=0.000) | 0.1421 (P=0.000) |
| *Entertainment* | 0.1166 (P=0.000) | 0.0066 (P=0.728) | 0.0057 (P=0.764) |
| *Fast Food Restuarants* | 0.1042 (P=0.000) | 0.0985 (P=0.000) | 0.0630 (P=0.001) |
| *Grocery Stores* | 0.2174 (P=0.000) | 0.1717 (P=0.000) | 0.1194 (P=0.000) |
| *High-Tech Industry* | - 0.0222 (P=0.245) | - 0.0206 (P=0.279) | - 0.0222 (P=0.486) |
| *Museums* | 0.0729 (P=0.000) | 0.0424 (P=0.026) | - 0.0056 (P=0.767) |
| *Office Buildings* | 0.2557 (P=0.000) | 0.2280 (P=0.000) | 0.1615 (P=0.000) |
| *Office Parks* | 0.0074 (P=0.698) | 0.0024 (P=0.899) | 0.0037 (P=0.845) |
| *Office - Miscellaneous* | 0.0718 (P=0.000) | 0.0486 (P=0.011) | 0.0587 (P=0.002) |
| *Parks* | 0.1206 (P=0.000) | NA | 0.0211 (P=0.268) |
| *Playgrounds* | 0.0665 (P=0.000) | NA | 0.0168 (P=0.379) |
| *Recreational* | - 0.0093 (P=0.627) | - 0.0176 (P=0.356) | 0.0147 (P=0.442) |
| *Restuarants and Taverns* | 0.2757 (P=0.000) | 0.2432 (P=0.000) | 0.1423(P=0.000) |
| *Retail - Large* | 0.1302 (P=0.000) | 0.1108 (P=0.000) | 0.0419(P=0.028) |
| *Retail - Neighborhood* | 0.2965 (P=0.000) | 0.2920 (P=0.000) | 0.1456 (P=0.000) |
| *Vacant Parcels* | - 0.0369 (P=0.053) | NA | 0.0160 (P=0.401) |

**Table 16: Correlations between Land Use Measures and the Percentage of Household Walk Trips**

(Controlling for Street Connectivity and Sidewalk Density)

When controlling for the effects of street connectivity and sidewalk density[2], the correlation coefficients between rentable building area and percentage of household walk trips begins to match that of the number of attractions, particularly for neighborhood retail and commercial office buildings. This is as one would expect: when urban design characteristics that encourage walking, such as the provision of an adequate pedestrian network, are held constant among land uses, the total area of accessible attractions should be better related to walking.

It is also important to note that controlling for sidewalk density and street connectivity also decreased the strength of the correlations between walking and the number of attractions. This too, is, as one would expect. The initial strength of the correlations between walking and the number of unique attractions was due to design characteristics associated with areas that have a large number of unique attractions, and not the attractions themselves. When controlling for the influence of at least two of these characteristics – street connectivity and sidewalk density – the measure lost some of its strength because it could no longer "absorb" its association with these design elements.

This suggests that, while the number of attractions is most strongly correlated with the percentage of household walk trips, other moderating variables are in fact responsible for some of this correlation, and that the design of the pedestrian realm may be as important as the land uses themselves. Older neighborhoods, which tend to have more unique attractions, also have connected street networks, sidewalks, and other design elements conducive to walking. While design characteristics are difficult to operationalize for statistical analysis, the correlation results make it clear that these characteristics play an important role in explaining walking trips. When controlling for the two design characteristics, rentable floor area appears to be a better land use measure for some of the land use types than the

2 The sidewalk variable within the parcel database upon which this assessment is based is incomplete.

number of unique attractions.

### a) Considering Educational Facilities

In the initial and second set of correlations, the relationship between educational use measures and the percentage of household walk trips remained relatively constant. The number of educational facilities, rather than their size, consistently proved to be better associated with household walk trips. We suspect that the reason the rentable area of the facility proved to be less strongly related to walking than did the number of school facilities is due partly to of the nature of schools themselves. While school facilities may vary in size, school boards tend to hold the number of students per facility relatively constant for educational purposes – pedagogically, schools are more effective when total school enrollment is kept below a certain level. Assuming this is, in fact, the case, one would expect the number of school facilities to be better related with walking than would the actual size of the facilities.

### b) Considering the Role of Parks

Interestingly, the square footage of available park space (measured by the total parcel area of all parks in the household buffer) did not prove as important as the number of parks in either of the sets of correlations – indeed, in neither correlation did size even register as statistically significant, let alone strongly correlated. For planners, this suggests that providing more parks, even if the parks are small, may be more useful in encouraging walking than would providing a single large park. While larger parks are useful for certain types of recreational activities, smaller parks are what appear to matter most for walk trips. Smaller parks provide "outdoor rooms" for a community: places to read, congregate, or watch people pass by. Smaller parks serve more than just recreational purposes; they also enhance the attractiveness of the environment. Jane Jacobs (1961), in an illuminating essay on the functions of park space, comments on the aesthetic role that small parks can play:

> *"Some of these [parks], if sufficiently small, can do another job well: simply be pleasing to the eye. San Francisco is good at this. A tiny triangular street intersection leftover, which in most cities would either be flattened into asphalt or else have a hedge, a few benches and be a dusty nonentity, in San Francisco is a fenced miniature world of its own, a deep, cool world of water and exotic forest, populated by the birds that have been attracted. You cannot go in yourself. You do not need to, because your eyes go in and take you farther in this world than feet could ever go."*

As Jacobs observed, small parks that serve no obvious functional purpose can nevertheless have an important effect on the attractiveness of a community. Unlike large sweeping parks, such as Grant Park in Chicago, an individual cannot enjoy these small parks when racing by on their car. To appreciate them, you have to be on foot.

None of this is to suggest that larger parks should be neglected in favor of smaller parks, but that uses of parks vary greatly, and that planners should pay attention to providing a range of park options that complement a community. Large parks, such as Gasworks Park, are excellent for kite flying, Frisbeethrowing, or a game of touch football, and are essential in meeting the recreational needs of a community. Smaller parks simply cannot accomplish these more "active" recreational activities. But smaller parks can - and do, if designed appropriately - create an environment that encourages pedestrianism by not only providing a destination, but by enhancing the streetscape as well. Planners seeking to encourage pedestrianism may do well to encourage the design of smaller parks that enliven the streetscapes of the communities they serve.

While correlations are useful for examining relationships between variables (when controlling for the influence of other variables, such as household demographics), they are useful only to describe the relationship between two variables at a time, such as walking and the square footage of retail space. A further shortcoming is that correlations cannot predict how changes to an independent variable, such as retail square footage, will affect the dependent variable. To better understand the relationship between land use characteristics (the independent variables) and a travel behavior such as walking (the dependent variable), a different types of statistical tests are needed.

Two statistical tests are detailed in the next two sections. The first used a logistical regression model at the person and one kilometer household buffer level. The dependent variable was a dichotomous variable, indicating whether or not a person made at least one walk trip over the two day survey reporting period. Independent variables were demographics and quadrants of urban form variables. The second statistical test used a multivariate linear regression model at the household and one-quarter miles household buffer level. The dependent variable was the percent of walk trips at the household level. The independent variables were demographics and continuous urban form variables.

## 3. Estimating Odds of Walking – Person Level, Non-Work Logistical Regression

The odds of someone reporting at least one walk trip over the two day survey reporting period was investigated using logistical regression analysis. The logistical regression results (Table 17) indicate that, when controlling for demographics, the odds of walking increased by 20 percent[3] for each additional park and 21 percent for each additional educational facility within a kilometer distance (buffer) from where King County residents live. It is anticipated that this relationship is non-linear and that smaller increases in walking will likely result as demand for parks and schools is approached and met. Survey respondents were divided into four groups (quartiles) based on their community's[4] level of street connectivity, residential density, and into four groups based on the number of retail establishments. When controlling for income, age, educational attainment, and gender, each quartile increase in:

- the number of intersections per square kilometer corresponded with a 14 percent increase

3 Odds are determined by subtracting one from the Exp(B) value and multiplying by 100: (Exp(B) -1)*100.
4 One kilometer road networked based buffer from household.

in the odds of walking for non-work travel;

- the levels of residential density corresponded with a 23 percent increase in the odds of walking for non-work travel; and
- the number of retail establishments corresponded with a 19 percent increase in the odds of walking for non-work travel.

| Independent Variables | B | S.E. | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|
| Age | -.013 | .002 | 37.449 | 1 | .000 | .987 |
| Educational attainment | .112 | .023 | 23.087 | 1 | .000 | 1.119 |
| Income –household, annual | .060 | .023 | 6.655 | 1 | .010 | 1.062 |
| Vehicles per household | -.297 | .045 | 44.594 | 1 | .000 | .743 |
| Quartiles of Intersections per square kilometer at home buffer | .136 | .036 | 14.143 | 1 | .000 | 1.146 |
| Quartiles of residential density (units per residential acres) at home buffer | .209 | .044 | 22.553 | 1 | .000 | 1.232 |
| Quartiles of number of neighborhood retail locations at home buffer | .177 | .050 | 12.841 | 1 | .000 | 1.194 |
| Number of parks at home buffer | .179 | .064 | 7.769 | 1 | .005 | 1.196 |
| Number of education related parcels at home buffer | .191 | .035 | 29.610 | 1 | .000 | 1.210 |
| Constant | -3.479 | .409 | 72.443 | 1 | .000 | .031 |

**Table 17: Walk or Not – Logistical Regression (valid N (people, listwise) =6,238)**

The tables below provide the descriptives for the independent variables.

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Did the person make at least one non-work walk trip over the two day survey period? | 6,585 | .00 | 1.00 | .1578 | .36456 |
| Age | 6,585 | 0 | 99 | 38.24 | 21.459 |
| Educational attainment (categorical) | 6,585 | 1 | 6 | 3.44 | 1.889 |
| Vehicle per household | 6,585 | 0 | 8 | 2.14 | 1.104 |
| Income—household, annual (categorical) | 6,585 | 11 | 18 | 16.24 | 1.750 |
| Number of Parks | 6,518 | .00 | 7.00 | .1361 | .47109 |
| Number of education related parcels | 6,518 | .00 | 27.00 | .4491 | 1.00456 |

**Table 18: Descriptives of Continuous & Categorical Variables Used in Walk Logistical Regression**

*Notes:* Educational Attainment categorical values: 1 = Less than high school, 2 = High school graduate, 3 = Some college, Vocational Technical, 4 = Undergraduate/Bachelors degree, 5 = Graduate/Post-graduate degree Income (household, annual) values: 11 = Less than

$10,000, 12 = $10,000 to $14,999, 13 = $15,000 to $24,999, 14 = $25,000 to $34,999, 15 = $35,000 to $44,999, 16 = $45,000 to $54,999, 17 = $55,000 to $74,999, 18 = $75,000 or more

| Variable | Descriptives | Quartile # | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Intersections per square kilometer | N (household 1km buffers) | 1588 | 1606 | 1590 | 1575 |
| | Minimum | 0 | 47.94 | 64.26 | 83.04 |
| | Maximum | 47.78 | 64.23 | 83.03 | 222.89 |
| Residential units per residential acre | N (household 1km buffers) | 1551 | 1550 | 1557 | 1580 |
| | Minimum | 0.62 | 4.25 | 5.63 | 11.26 |
| | Maximum | 4.25 | 5.62 | 11.26 | 121 |
| Number of neighborhood retail locations | N (household 1km buffers) | 4497 | 494 | 1368 | |
| | Minimum | 0 | 1 | 2 | |
| | Maximum | 0 | 1 | 76 | |

**Table 19: Descriptives of Quartiled Variables Used in Logistical Regression**

## 4. Estimating Percent of Walk Trips – Household Level Linear Regression Analysis

Multivariate linear regression is a powerful statistical model that provides information on the strength of the relationship between a host of independent variables and a dependent variable – in this case, the percent of household walk trips. In developing a regression model, the research team chose those measures of land use within quarter mile household buffers that, from the correlation results, appeared to best explain the variation of walking rates among households. Correspondingly, rentable square feet was used to measure the effect of the following land uses on walking:

- Civic Attractions, including churches, auditoriums and fraternal organizations
- Doctor and Dentist Offices
- High Tech Industrial
- Office Buildings
- Office Parks
- Miscellaneous Office Space
- Large Retail
- Neighborhood Retail

The total number of unique attractions was used to measure the influence of the following variables on walking:

- Convenience Stores
- Educational Facilities
- Entertainment Attractions, including movie theaters, sports arenas and miniature golf sites
- Fast Food Restaurants
- Grocery Stores
- Museums
- Parks
- Playgrounds
- Recreational Attractions, including bowling alleys, golf courses, amusement parks, and skating rinks
- Restaurants and Taverns
- Vacant Parcels

In addition to the measures described above, two urban form measures were included in the model to measure their effect on walking rates:

- Net residential density
- Street connectivity (intersection density)

These two urban form measures have traditionally been considered the most important factors in explaining walking trip rates. With this research, we wanted to see if the relationships between density and street connectivity held after neighborhood land uses were desegregated and tested for their separate influence.

Finally, to control for the influence of household demographics on household walking trip rates, household size, household income, and the number of vehicles per household were used as control variables. Table 20 provides the regression results.

| Variable | Beta Coefficient | t Statistic | Significance |
|---|---|---|---|
| Household Size | 0.056 | 2.794 | 0.005 |
| Household Income | 0.028 | 1.442 | 0.149 |
| Number of Household Vehicles | -0.123 | -5.862 | 0.000 |
| Net Residential Density | 0.084 | 3.867 | 0.000 |
| Intersection Density | 0.076 | 4.037 | 0.000 |
| # Educational Facilities | 0.158 | 8.397 | 0.000 |
| # Parks | 0.057 | 3.223 | 0.001 |
| # Groceries | 0.053 | 2.550 | 0.011 |
| # Civic Attractions | 0.046 | 2.234 | 0.026 |
| Retail-Large Rent Area | 0.061 | 3.249 | 0.001 |
| Retail-Neighborhood Rent Area | 0.175 | 8.427 | 0.000 |
| # Restaurants/Taverns | 0.068 | 3.029 | 0.002 |

Dependent Variable: Percentage of Household Walk Trips

R2 = 0.240
F Statistic = 68.142
Number of Observations = 2604

**Table 20: Percentage of Household Walk Trips - Linear Regression**

## a) Model Results

The best-fit model explained 24 percent of the variance in rates of walking among survey households, and all of the variables entered with the expected signs.

### (1) Control Variables

Of the control variables, both household size and the number of household vehicles were significantly related to walk rates. Household income did not enter the model at a statistically significant level.

#### *(a) Household Size*

Larger households have more walkers, and consequently have the ability to generate more walk trips. This variable has only a weak effect on walking, however, with a beta coefficient of 0.056.

#### *(b) Vehicles Per Household*

The number of vehicles per household has a moderately negative relationship with walking, with a beta coefficient of –0.123. The negative relationship is undoubtedly in response to a combination of two factors. First, households owning more vehicles have a greater opportunity to drive, and having made the investment in an additional automobile, appear to be making use of this investment. Secondly, in areas where there are few destination attractions within walking distance, additional automobiles are necessary to accommodate household travel demand.

### *(c) Household Income*

The third control variable, household income, did not prove to be significantly related to the percentage of household walk trips. This is most likely due to a combination of factors. First, highly walkable areas such as Seattle's Capitol Hill tend also to have increased housing costs associated with them, limiting the number of lower income households that can reside there. Conversely, lower income households tend to have fewer vehicles and are more reliant on walking than wealthier neighborhoods. These two factors most likely cancel each other out, causing the failure of this measure to enter significantly into the model.

## (2) Urban Form Variables

### *(a) Net Residential Density*

Net residential density, which is often the variable most related to the percentage of household walking trips, was found to be relatively weak in this model. It has a statistically significant beta coefficient of approximately 0.08. The reason for this appears to be because of the disaggregate nature of the land use data used in this model, which prevented the research team from isolating the effect of net residential density on walking while accounting for the mixed land uses typically associated with it. In the past, lacking disaggregate land use measures with which to describe the variation in land use mixing around households, researchers have been forced to fall back on density to capture the effect of land use on walking. High density areas are typically better mixed than low-density areas because they can sustain more destination choices. More residents per acre means more potential shoppers and diners, and hence the ability to have more, or larger, shops and restaurants. As these results show, however, density by itself has only a weak relationship with walking – the presence of mixed land uses and meaningful trip destinations are more important for encouraging walking.

While these findings may disappoint advocates of higher residential densities, it is important to recognize that with the exception of leisurely walking, people don't travel for the sake of traveling – they travel to accomplish a purpose. More housing units per acre don't translate into meaningful destinations – they simply represent denser housing. Before we underplay the importance of density it is important to recognize that density is essential for sustaining the shops, restaurants and other uses that encourage people to walk. Without a sufficient market, businesses such as shops and restaurants can't sustain their operations, and will ultimately be forced to close. Increasing the residential density around these land uses helps provide them with the market they need. The relationship between land use mixing and residential density is symbiotic. The finding that density alone plays less of a role in influencing mode share than was previously thought is significant, because it moves us beyond the simple guidance that "higher density is better" to a more nuanced appreciation of the influence of density and land use on travel behavior.

### *(b) Street Connectivity*

Street connectivity, or intersection density, was also found to have a significant but weak correlation with walking rates, with a beta coefficient of approximately 0.08. The weak correlation between this measure and walking is most likely due to a combination of factors, both of which make sense. As with net residential density, intersection density has traditionally been strongly correlated with the amount of land use mixing in an area. Older, traditional neighborhoods, which typically play host to a variety of land uses, also tend to have high levels of network connectivity. Controlling for the presence of these uses reduces the strength of intersection density. More intersections don't translate into more destination attractions. This reinforces the findings of the correlation analysis – intersection density and mixed uses play complementary roles in encouraging people to walk.

The second factor explaining the weak correlation between intersection density and walking is the use of neighbourhood level buffers around households, rather than the more typical traffic analysis zone or census tract levels used by other studies. The larger areas used by earlier studies often have no direct link to the location of an individual's household, or the destinations that were accessible within a given distance from it. At these larger geographic scales intersection density increases in importance as an explanation of walking trip rates.

In this study, the use of parcel-level data allowed the researchers to draw network buffers around the household and capture the parcels that were within walking distance. This disaggregate approach allowed the walking distance among households to be held constant, so that the buffer around each household represents a five minute walk. Using this approach made the model much more sensitive to the effect of intersection density at the individual household level and removes the extraneous effects of land use from the measure, resulting in a weaker relationship between intersection density and walking trip rates. Again, as with net residential density, intersection density is still an important factor in encouraging people to walk, but not as important as has been suggested in earlier studies.

### (3) Land Use Variables

The final series of measures included in the model related to individual land uses themselves. Of these, the two with the most direct influence on walking proved to be the square footage of neighborhood retail, and the number of educational facilities in the buffer area. Both had positive, moderately strong relationships with the percentage of household walk trips – with beta coefficients of 0.175 and 0.158, respectively.

The remaining land use variables, which included parks, restaurants and taverns, civic attractions, grocery stores, and the rentable floor space of large retail attractions, entered with relatively weak but significant beta coefficients of less than 0.07. The research team hypothesized, however, that their combined influence on encouraging people to walk is undoubtedly greater than their influence individually.

To test this assertion, the researchers developed a composite variable, *walkvars*, that combined the sum of these individual attractions together, as defined in Equation 5-1 below:

**WALKVARS** $= \sum(Zparks + Zrestaurants + Zcivic + Zgrocery + ZRetail_{Large})$ (5-1)

Where:Zparks = the Z score of the number of parks

Zrestuarants = the z score of the number of restaurants and taverns

Zcivic = the z score of the number of civic attractions

Zgrocery = the z score of the n umber of grocery stores

$ZRetail_{Large}$ = the z score of the rentable floor are of large retail

The Z-scores of the variables were used rather than the raw numbers to place the units of measurements between the uses on a common scale. For example, while parks are measured by the number of individual parks, large retail attractions are measured in rentable floor area. Assuming a neighborhood has 100,000 square feet of large retail space and two parks, the raw aggregate of these measures would be 100,002. Z-scores distribute the range of values along a normal curve, providing a consistent unit of measurement.

The Walkvars variable was substituted for the park, restaurants, civic, grocery and large retail measures in the model and the regressions were re-run. Table 21 illustrates the results.

**Walk Trip Regression 2**

| Variable | Beta Coefficient | Significance |
|---|---|---|
| Household Size | 0.055 | 0.005 |
| Household Income | 0.028 | 0.147 |
| Number of Household Vehicles | -0.122 | 0.000 |
| Net Residential Density | 0.085 | 0.000 |
| Interesection Density | 0.075 | 0.000 |
| # Educational Facilities | 0.157 | 0.000 |
| Retail-Neighborhood Rent Area | 0.180 | 0.000 |
| WALKVARS | 0.171 | 0.000 |

Dependent Variable: Percentage of Household Walk Trips

R2 = 0.240

Number of Observations = 2604

**Table 21: Model 2 for the Percentage of Household Walk Trips.**

The new model explained exactly the same amount of variance as the first model, with an $R^2$ of 0.24. As expected, the composite measure WALKVARS has a stronger beta coefficient – 0.171 – than did any of the individual measures that comprised it, indicating that the composite measure is a stronger predictor of household walk trips than are any of the individual variables. This furthers the assertion that mixing uses together is an important factor in encouraging people to walk.

### b) Speculating on Excluded Variables

Given the strength of the preliminary correlations between office building square footage and the percentage of household walk trips, one would have expected it to enter significantly into the model, which it did not. The reason for this seems to be because of the fact that most people either cannot, or choose not to, live within walking distance of their place of work. Despite the fact that work trips accounted for 18% of the total trips generated by households, only 741 of the 6185 work trips in this study – 12% – were accomplished by walking. Moreover, there is no evidence to suggest that those individuals walking to work actually worked in commercial office buildings – it is just as possible that walkers work in retail, service or some other industry.

Although not significantly related to walking, both office parks and fast food restaurants entered with negative beta coefficients, as did entertainment and recreational activities. These variables were not strong predictors of walking, nor would one expect them to be – recreational activities, such as bowling and golf, often have equipment that is too heavy to be carried comfortably while walking. There is no reason to suggest that other recreational or entertainment activities, such as miniature golf, would encourage people to walk, either.

### c) Policy Implications

This analysis of the relationship between walking, land use and urban form characteristics in many ways confirms what planners have known all along – that the creation of walkable environments with mixed land uses, retail-supportive residential densities and adequate connectivity between uses encourages people to walk. None of the individual characteristics modeled in this analysis proved to be a particularly strong predictor of walking trips – the strongest variable, neighborhood retail square footage, had a beta coefficient of only 0.17, a moderately weak relationship at best. Still, it is not the presence of individual characteristics, but the collective effect of land use mixing and density that influences walking. By simultaneously increasing a number of the measures, including density, the square feet of retail space, the number of restaurants and parks, and street connectivity, planners may be able to bring about dramatic transformations in the number of household trips accomplished by walking.

***Box 1: Interpreting Partial Correlations***

The Pearson's R coefficient provides an indicator of the strength of the relationship between variables on a scale of 0 to 1, with a value of 1 indicating that the variables are perfectly related, and a 0 indicating that there is no relationship between the variables. Negative values indicate an inverse relationship between the variables – for example, as the number of vacant parcels in an area goes up, the percentage of walking trips goes down.

The statistical significance (P value) of each correlation is provided in parentheses beside each of the correlations. This value indicates whether or not the correlation is statistically significant, or, in layman's terms, how likely that the relationship between the two variables is a real relationship, and not just a random coincidence. P values range from 0 to 1, with a 0 indicating that there is little likelihood that the relationship is the result of a random occurrence, and a 1 indicating that the relationship is completely random. Typically, a value 0.05 or lower indicates that the relationship is statistically significant.

### (1) Focus on Encouraging Land Uses that Complement Walking Behavior

As the model results illustrated, simply having multiple uses near one's home is no guarantee that a person will walk to access them. Of the uses included in this study, the following have proven to be best related to walking:

- Neighborhood Retail
- Educational Facilities
- Grocery Stores
- Restaurants and Taverns
- Parks
- Large Retail Attractions

While some neighborhoods naturally evolve into specialized shopping or entertainment districts, planners should seek to encourage a complementary host of these uses within walking distance of households. Independently, none of the individual land uses has a strong effect on walk trips, although collectively their influence can be great. For those wishing to encourage walking as a travel mode, better land use mixing is responsible for increasing the likelihood that people will walk.

Large numbers of vacant lots, signatures of urban decline and decay, should be prevented. Unsurprisingly, vacant lots are negatively related to walking, either because they equate to fewer walking attractions, or because the neglect and disrepair of large numbers of these lots create an environment hostile to pedestrians.

### (1) Large Retail

Planners have long resisted large retail uses because of their ability to force downtown shopping districts into decline, and because of their negative aesthetic impact. That large retail should prove significant in explaining walk trips forces a reconsideration of the role that it can play in encouraging walk trips. On the one hand, it is essential to remember that there is nothing innately bad about large retail, as long as it is sited in a way that complements the surrounding area. Design guidelines can be used to prohibit the least desirable components of these facilities, such as the large surface parking lots and deep setbacks. As with all land uses, large retail stores have their place.

On the other hand, although large retail did have a significant and positive relationship with walking, it is important to recognize that this relationship is weaker than that between smaller neighborhood retail and walking. In areas where large retail can force neighborhood retail into decline, the decision to incorporate large retail may functionally reduce the number of household walk trips. In these cases, planners may seek to develop stringent design controls on the physical form that large retail may take, and further, to exclude these uses from neighborhood shopping districts. In suburban areas where neighborhood shopping is unavailable, but where a strong market for a large retail store may exist, planners should consider the possibility of incorporating large retail into the overall design of the neighborhood, and fostering a strong pedestrian link to the development. By encouraging creative site designs and land use configurations in areas with large retail establishments, planners may be able to turn a burden into a benefit.

### (2)Use the Right Land Use Measure When Formulating Policy

One of the more interesting findings of this study from an implementation perspective is that for some land uses, rentable floor area proved to be the best measure with the strongest relationship to household walking trip rates - whereas for other land uses, the number of unique attractions proved the measure with the strongest relationship to walking. Selecting the right unit of measurement when specifying land uses in planning guidance documents will allow practitioners to better measure their progress as they attempt to achieve goals such as encouraging use of non-motorized travel modes.

Appropriate performance measurement is necessary for successful implementation. When developing land use guidelines to encourage walking in development review and planning, this study recommends that guidelines for retail and commercial uses be presented in terms of their rentable square feet. Guidelines for parks, groceries, educational facilities, and restaurants would best be presented in terms of the number of unique attractions in the development, planning area or neighborhood.

***Box 2: Considering "Self-Selection"***

"Self-Selection" is a concept that suggests that individuals already predisposed to walk choose to live in walkable places. Advocates of self-selection argue that land use does not directly affect travel behavior – that instead, individuals who desire to walk choose to live in places with land use patterns that encourage walking. Because these people represent a unique group, statistical results that show higher incidences of walking in walkable areas cannot be used to generalize to populations as whole.

While the self-selection argument poses an interesting logical puzzle for planners, the reality is that when walkable places are created, people living in them walk. If the self -selection argument is true, then the supply of walkable neighborhoods has not yet met demand, as the higher property values for walkable neighborhoods, such as Capital Hill and Queen Anne Hill in Seattle, demonstrate. If the self-selection argument is wrong – if in fact, building walkable environments does encourage people to walk more -- then planners can and should facilitate the creation of walkable environments whenever possible.

## III. Transit

This study seeks to compare the effects of land use patterns at both the origin and destination end of transit trips to better understand how changes in land use configurations, street network design, and investments in pedestrian infrastructure can encourage transit use. At the outset, it is important to this particular project to document the fact that a considerable synergy exists between walking and transit. We found a pearson correlation coefficient of $r = 0.2110$ at the 99.99 significance level between the number of walk and transit trips per person when controlling for income and household size in a sample of 4,037 participants in the County. Transit riders are indeed walkers.

### A. Transit Riders and Trip Purposes

Data from the Puget Sound Household Activity survey was used to evaluate the impacts that land use strategies have on transit effectiveness. These results are based on the 7,548 respondents within King County. Of these respondents, 606 used transit on at least one of the two days during which the survey was conducted.

Compared to all respondents from the King County sample, transit users are slightly more likely to be female, and be non-white (see Table 22 and Table 23). Interestingly, transit riders are likely to be more educated than we found across all respondents at the county level (Table 24). They are also more likely to have a lower household income and have fewer vehicles as revealed in Table 25 and Table 26. Finally,

Table 27 through Table 28 show transit riders are slightly older and have smaller households than we found across all respondents at the county level.

| Gender | King County | Transit Riders | Transit Difference |
|---|---|---|---|
| Male | 48% | 47% | -2% |
| Female | 51% | 53% | 2% |
| Missing/Refused | 0% | 0% | 0% |

**Table 22: Gender of Transit Riders Compared with King County Survey Respondents**

| Ethnicity | King County | Transit Riders | Transit Difference |
|---|---|---|---|
| White/Non-Hispanic | 88% | 84% | -3% |
| Hispanic/Latino | 2% | 1% | 0% |
| African American | 2% | 3% | 1% |
| Asian/Pacific Islander | 5% | 6% | 1% |
| Native American | 1% | 1% | 0% |
| Other | 1% | 1% | 0% |
| Missing/Refused | 2% | 3% | 1% |

**Table 23: Ethnicity of Transit Riders Compared with King County Survey Respondents**

| Educational Attainment | King County | Transit Riders | Transit Difference |
|---|---|---|---|
| Less than High School | 23% | 8% | -15% |
| High School | 13% | 10% | -3% |
| Some College | 18% | 19% | 2% |
| Technical/Vocational | 2% | 2% | 0% |
| Undergraduate/Bachelors | 24% | 30% | 6% |
| Graduate/Post-Graduate | 18% | 29% | 10% |
| Missing/Refused | 1% | 1% | 0% |

**Table 24: Educational Attainment of Transit Riders Compared with King County Survey Respondents**

| Household Income | King County | Transit Riders | Transit Difference |
|---|---|---|---|
| Less than $10,000 | 1% | 3% | 2% |
| $10,000 to $14,999 | 1% | 3% | 1% |
| $15,000 to $24,999 | 5% | 7% | 3% |
| $25,000 to $34,999 | 7% | 9% | 2% |
| $35,000 to $44,999 | 12% | 12% | 0% |
| $45,000 to $54,999 | 13% | 13% | 0% |
| $55,000 to $74,999 | 20% | 19% | -1% |
| $75,000 and Greater | 28% | 20% | -7% |
| Missing/Refused | 12% | 13% | 1% |

**Table 25: Household Income of Transit Riders Compared with King County Survey Respondents**

| Household Vehicles | King County | Transit Riders | Transit Difference |
|---|---|---|---|
| Mean Vehicles | 2.1 | 1.5 | -0.6 |
| Std. Dev | 1.1 | 1.1 | 0 |

**Table 26: Household Vehicles**

| Age | King County | Transit Riders | Transit Difference |
|---|---|---|---|
| Mean Age | 38.5 | 40.8 | 2.3 |
| Std. Dev | 21.7 | 16.5 | -5.2 |

**Table 27: Age**

| Household Size | King County | Transit Riders | Transit Difference |
|---|---|---|---|
| Mean Size | 3 | 2.5 | -0.5 |
| Std. Dev | 1.4 | 1.3 | -0.1 |

**Table 28: Household Size**

Table 29 shows the top three purposes for trips made by transit are to return home (32.7%), work (31.7%) and changing modes of travel (10.3%). Table 30 removes the first two purposes (home and mode change), which really are more derived purposes – in that for most trips they occur because of the purpose of traveling to outbound destination.

| Main Trip Purpose | N (trips) | Percent |
|---|---|---|
| Home | 640 | 32.7 |
| Work | 621 | 31.7 |
| Work related (to location not regular workplace or home) | 29 | 1.5 |
| School - Junior college, university, vocational/trade | 56 | 2.9 |
| School - Daycare, K-12 | 23 | 1.2 |
| Incidental shopping | 96 | 4.9 |
| Major shopping | 20 | 1 |
| Personal business | 76 | 3.9 |
| Medical | 28 | 1.4 |
| Other services (specified) | 1 | 0.1 |
| Eat out | 28 | 1.4 |
| Social/Recreational | 106 | 5.4 |
| Civic activities | 15 | 0.8 |
| Church activities | 1 | 0.1 |
| Pick-up/Drop-off person at work | 1 | 0.1 |
| Pick-up/Drop-off person at school/daycare | 10 | 0.5 |
| Pick-up/Drop-off person at other | 7 | 0.4 |
| Change mode of travel | 202 | 10.3 |
| Total | 1,960 | 100 |

**Table 29: Transit Trip Purposes (all purposes)**

When home and mode change are removed from the trip purpose list, transit is primarily used for the journey to work (55 percent), with no more than 9 percent of trips allocated to any other purpose (Table 30).

| Trip Purpose* | Percent of Trips |
|---|---|
| Work | 55% |
| Social/Recreational | 9% |
| Incidental Shopping | 8% |
| Personal Business | 7% |
| School - junior college, university vocational/trade | 5% |
| School - daycare, K-12 | 3% |
| Other** | 12% |

*Trips classified as "Home" trips and "Change Mode" trips have been excluded.

**Other trips include all trip purposes that individually account for 2% or less of the total percentage of transit trips.

**Table 30: Transit Trip Purposes (not including "home" and "change mode")**

Of primary interest is the distinction between transit captive and transit choice riders. Households without a car most often integrate walking and transit to accomplish their travel needs. "Choice" riders select modes based on their level of competitiveness in terms of time or per trip cost when compared to a private automobile. Where free parking is unavailable, or where trip distances and traffic congestion on general purpose lanes make transit faster than a car, choice riders will switch to transit to accomplish their travel needs (Cervero 1998). Because most work trips occur during the peak AM and PM periods, when traffic congestion is at its highest, the time savings associated with transit may encourage people to switch from their automobiles to transit. Of course, this can only be the case where transit has an exclusive right of way within a given corridor. From a door-to-door perspective, transit is seldom faster than driving; however, where the travel time on transit approaches the private vehicle, increased out of pocket expense from parking on a repeated basis can wrench even the most staunch auto enthusiasts from their cars.

Efficient land use planning is required for travel times to become even marginally competitive between transit and driving. Urban form directly influences the time differential between transit and auto travel. Individuals must not only be able to access a transit station near their home location, but must also be able to conveniently access their destination via transit as well. This report hypothesizes that the ability to access secondary trip destinations also factors importantly into the decision to use transit.

## B. Transit Database Development

Since the majority of transit trips were undertaken to arrive at work destinations, person-level data was extracted from the larger household activity survey for all individuals taking work trips during the two-day travel survey. Using spatial coordinates for a person's place of work, we geo-located each workplace and created quarter-mile network buffers around each site. Once these sites were created, we then captured each individual parcel located within the buffer area to develop a land use database. Merging this database with the household-level database developed earlier allowed us to model the effects that land uses at both the home and workplace end of the trip have on transit ridership.

Because workplaces were used for destination ends, we limited this study to include only individuals who were employed at the time the survey was conducted. Our focus was solely within King County rather than for the four-county region in which the Puget Sound Household Activity Survey was conducted. Of the roughly 14,000 survey respondents, 4304 had workplaces located in King County, and of these, 3233 also has residences in the county. Given that the place of employment is the explicit primary destination of these transit-to-work trips, it becomes especially important to analyze the influence that secondary destinations – essentially the other land uses around the employment location - have on the decision to take transit to work. In other words, it is implicit that the subset of trips examined in this section of the study is associated with a transit level of service which makes transit use competitive with driving. The study seeks to determine which other land use factors help to encourage travelers to make transit their choice for the trip to work.

## C. Correlation Analysis

As a measure of transit ridership, this study uses the percentage of personal work trips accomplished using transit. While useful for analyzing transit ridership, this measure does have some shortcomings that must be acknowledged. First, most people's travel patterns are relatively fixed for work trips – a person typically uses only one mode to travel to and from work, and their use of this mode is consistent from day to day, limiting the amount of variation in the data. Because of this phenomenon, the percentage of household work trips accomplished using transit is distributed in a "bi-modal" manner - or largely at either end of the data range – with most cases entering with values of either 0 percent or 100 percent. This distribution is shown in Figure 32 below.

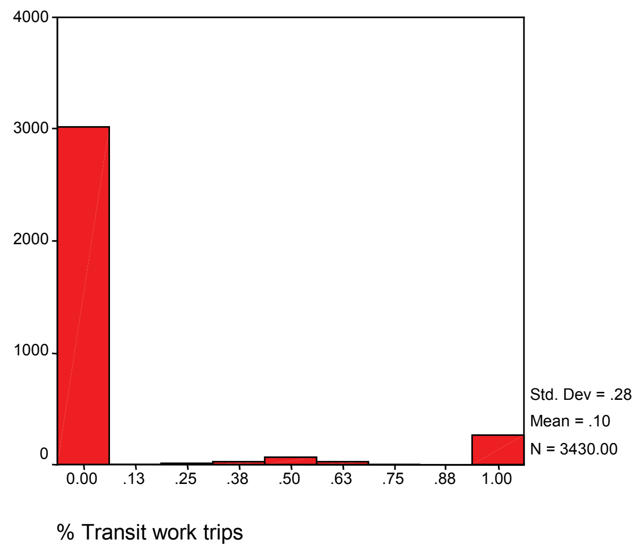


**Figure 32: Distribution of the Percentage of Transit Work Trips for Survey Households**

While greater variation in the data would be desirable for the purposes of developing statistical models, the survey does not provide a better alternative measure of transit ridership. To better distribute the data, this study uses the natural log of the percentage of work trips taken by transit in the subsequent analysis.

As with the analysis of the relationship between land use and walking, this section first examines correlations between each of the individual land uses and an individual's propensity to use transit, and then employs a regression analysis to develop a predictive model of how different land use patterns at both the home and work ends of a trip can influence transit use for the trip to work.

### 1. Correlations between Land Use and Transit Ridership for the Trip to Work

Since characteristics such as household income, the number of household vehicles, and the size of a household all can influence mode choice, partial correlations that controlled for the effects of these variables were used to determine the strength of relationships between the percentage of transit work trips and land use types. As with the analysis of the relationship between walking and land use, three measures of each individual land use were employed – number of unique attractions by use, the rentable floor space by use, and the total parcel area dedicated towards each use.

### a) Employment Location Land Use and Transit Use

Table 31 displays the partial correlation coefficients, as well as their significance levels, for the land use surrounding respondent employment locations and the natural log of the percentage of transit work trips.

The rentable floor space in office buildings had the strongest correlation with the percentage of work trips accomplished using transit, with a partial correlation coefficient of 0.3704. The rentable floor space of civic uses, miscellaneous office space, and neighborhood-level retail also had moderate correlations as well. The number of restaurants and taverns had a slightly weaker, but still statistically significant relationship with the percentage of transit work trips.

The number of large retail establishments and entertainment attractions also has a moderate, positive relationship with transit work trips. The parcel area of vacant lots and the rentable floor space of fast food restaurants had negative, although relatively weak correlations with transit work trips.

Not surprisingly, the land uses best associated with the percentage of work trips a person takes using transit are also those associated with typical downtown areas: the amount of commercial office floor space, retail floor space, the number of large retail attractions, and number of office buildings. Large retail stores function as "anchor" stores in retail development projects; entertainment uses, such as movie theaters and sports attractions, and restaurants and taverns all show strong correlations with transit use. Fast food, high tech, office parks, vacant land, and land area in park use were found to be inversely associated with transit use ridership. These results have exceptional "face validity." One would expect to see more of these exact uses in areas where transit service is less viable.

| Land Use Type | Number of Attractions | Rentable Building Area | Total Parcel Area |
|---|---|---|---|
| *Civic* | 0.2388 (P=0.000) | 0.2463 (P=0.000) | 0.1764 (P=0.000) |
| *Convenience Stores* | - 0.0401 (P=0.023) | - 0.0693 (P=0.000) | - 0.0447 (P=0.011) |
| *Doctor-Dentist Offices* | 0.0007 (P=0.967) | 0.1475 (P=0.000) | - 0.0305 (P=0.083) |
| *Educational* | 0.0770 (P=0.000) | - 0.0136 (P=0.441) | 0.0602 (P=0.001) |
| *Entertainment* | 0.1880 (P=0.000) | 0.0261 (P=0.139) | 0.0261 (P=0.542) |
| *Fast Food Restuarants* | - 0.0401 (P=0.023) | - 0.0467 (P=0.008) | - 0.0452 (P=0.010) |
| *Grocery Stores* | 0.0245 (P=0.165) | - 0.0125 (P=0.480) | - 0.0266 (P=0.132) |
| *High-Tech Industry* | - 0.0303 (P=0.085) | - 0.0142 (P=0.420) | - 0.0367 (P=0.037) |
| *Museums* | 0.0838 (P=0.000) | 0.1543 (P=0.000) | 0.0316 (P=0.073) |
| *Office Buildings* | 0.3188 (P=0.000) | 0.3704 (P=0.000) | 0.2399 (P=0.000) |
| *Office Parks* | - 0.0404 (P=0.022) | - 0.0421 (P=0.017) | - 0.0337 (P=0.056) |
| *Office - Miscellaneous* | 0.2350 (P=0.000) | 0.2583 (P=0.000) | 0.2388 (P=0.000) |
| *Parks* | 0.1347 (P=0.000) | NA | - 0.0376 (P=0.033) |
| *Playgrounds* | - 0.0264 (P=0.134) | NA | - 0.0192 (P=0.275) |
| *Recreational* | - 0.0323 (P=0.067) | - 0.0364 (P=0.039) | - 0.0298 (P=0.091) |
| *Restuarants and Taverns* | 0.0913 (P=0.000) | 0.0999 (P=0.000) | - 0.0422 (P=0.017) |
| *Retail - Large* | 0.1786 (P=0.000) | 0.1317 (P=0.000) | - 0.0158 (P=0.369) |
| *Retail - Neighborhood* | 0.1699 (P=0.000) | 0.2733 (P=0.000) | 0.0410 (P=0.020) |
| *Vacant Parcels* | - 0.0816 (P=0.000) | NA | - 0.0922 (P=0.000) |

Note: Correlations use the Natural Log of the % of Person Transit Work Trips

**Table 31: Correlations Between Employment Location Land Use and Transit Work Trips**

(Controlling for Household Size, Income, and # of Household Vehicles)

The fact that vacant parcel area was negatively correlated with transit use is unsurprising. Transit requires compact development at destinations. Since the parcels lack a meaningful destination attraction, their presence should discourage people from using transit to access a given location. The larger the vacant area, the less attractive the destination. It may also be the case that the greater the number of vacant lots, the less safe an area feels, in which case travelers may be more inclined to take private vehicles than public transit.

Fast food restaurants also were also negatively correlated with transit use due to the fact that fast food establishments tend to be located in areas that are not transit supportive and are auto-oriented establishments with drive-through windows. These are typically located along arterial roadways with high traffic volumes, in low-density, unconnected areas with few pedestrian amenities - where it is difficult, and often dangerous, to walk. It is this form of fast food restaurant that appears to be responsible for the negative correlation between fast food and transit use.

### b) Household Location Land Use and Transit Use

While the land use at the destination of work trips undoubtedly plays a larger role in encouraging people to use transit, the research team hypothesized that certain land uses around the household may be related to increases in transit ridership as well. Table 32 shows the correlations between the land uses around a person's place of residence and the percentage of their work trips accomplished using transit.

The uses at the household location showed weaker overall relationships with transit use than the land uses at the employment end. All of the land use variables with statistically significant relationships were weakly correlated with the percentage of transit trips. The number of restaurants and taverns, with a partial correlation coefficient of 0.1650, had the strongest relationship. The number of grocery stores and the rentable square footage of both neighborhood retail and entertainment attractions all entered with statistically significant partial correlation coefficients at 0.10 or above.

Given that trips are undertaken to accomplish a meaningful trip purpose – in this case, traveling to work – it is unsurprising that the relationship between transit use and "destination" land uses at the household trip end are weak. Instead, the household land uses that show the strongest relationship with transit use are largely those that support a household's everyday needs – grocery stores, neighborhood scale retail, restaurants and entertainment attractions. Having these attractions near to transit stations reduces the need to make automobile trips, because household members using transit are able to make use of everyday shops and services on their way to and from work. When combined with the availability of adequate transit service, such an arrangement may make the ownership of multiple vehicles per household unnecessary.

| Land Use Type | Number of Attractions | Rentable Building Area | Total Parcel Area |
|---|---|---|---|
| *Civic* | 0.0736 (P=0.000) | 0.0605 (P=0.004) | 0.0234 (P=0.263) |
| *Convenience Stores* | 0.0592 (P=0.003) | 0.0582 (P=0.003) | 0.0229 (P=0.244) |
| *Doctor-Dentist Offices* | 0.0327 (P=0.099) | 0.0326 (P=0.100) | - 0.0002 (P=0.991) |
| *Educational* | 0.0340 (P=0.125) | 0.0310 (P=0.163) | 0.0272 (P=0.221) |
| *Entertainment* | 0.0918 (P=0.000) | 0.1078 (P=0.000) | 0.1103 (P=0.000) |
| *Fast Food Restuarants* | 0.0416 (P=0.034) | 0.0377 (P=0.055) | 0.0296 (P=0.133) |
| *Grocery Stores* | 0.1276 (P=0.000) | 0.1200 (P=0.000) | 0.1093 (P=0.000) |
| *High-Tech Industry* | 0.0584 (P=0.003) | 0.0246 (P=0.210) | 0.0261 (P=0.185) |
| *Museums* | 0.0045 (P=0.821) | - 0.0054 (P=0.786) | 0.0252 (P=0.201) |
| *Office Buildings* | 0.0768 (P=0.000) | 0.0361 (P=0.078) | 0.0388 (P=0.058) |
| *Office Parks* | NA | NA | NA |
| *Office - Miscellaneous* | 0.0094 (P=0.632) | - 0.0034 (P=0.864) | - 0.0070 (P=0.720) |
| *Parks* | 0.0412 (P=0.041) | NA | 0.0145 (P=0.471) |
| *Playgrounds* | 0.0330 (P=0.095) | NA | 0.0035(P=0.859) |
| *Recreational* | - 0.0046 (P=0.814) | - 0.0050 (P=0.799) | - 0.0416 (P=0.035) |
| *Restuarants and Taverns* | 0.1650 (P=0.000) | 0.1567 (P=0.000) | 0.1134 (P=0.000) |
| *Retail - Large* | 0.0520 (P=0.009) | 0.0025 (P=0.902) | 0.0493 (P=0.014) |
| *Retail - Neighborhood* | 0.1069 (P=0.000) | 0.1123 (P=0.000) | 0.0994 (P=0.000) |
| *Vacant Parcels* | - 0.0345 (P=0.098) | NA | 0.0560(P=0.007) |

Note: Correlations use the Natural Log of the % of Person Transit Work Trips

**Table 32: Correlations between Household Location Land Use and Transit Work Trips**

(Controlling for Household Size, Income, and # of Household Vehicles)

However, it is important to reiterate that the relationships between the land uses at the household end and transit usage are not very strong, and any influence they have on transit use decisions are probably minor. Nonetheless, the correlation results presented here suggest that the ideal land use pattern for encouraging transit use for the trip to work would be a limited number of secondary, household supporting land uses at the household end of the trip, and a large number of work destinations, as well as secondary shopping and entertainment attractions, on the employment end.

***Box 3: Interpreting Regression Models***

Regression models are useful for explaining how a variety of independent variables affect a dependent variable. Beta coefficients describe the strength and direction of the relationship between each of the independent variables and the dependent variables. Higher beta coefficients indicate stronger relationships. The beta coefficient provides a measure of the strength of the relationships between the independent and dependent variables when controlling for the effects of the other variables included in the model. Perhaps even more useful for planners, however, beta coefficients can also be used to predict how altering one of the independent variables, such as the amount of retail floor space, will affect the dependent variable, walking rates, giving planners a measure of the possible impacts of future decisions.

The $R^2$ value tells how much of the total variance in the dependent variable is explained by the model itself – i.e., how much of the differences in walking can be explained by the various household and land use measures that comprise the model. Values for $R^2$ can range from 0 to 1, with a value of 1 indicating that the model perfectly explains the dependent variable. While $R^2$ values close to 1 are desirable, social scientists have a difficult time obtaining strong $R^2$ values in practice. Data on human behavior is imperfect, and humans are unpredictable creatures. Still, given these limitations, regression models are a highly useful tool for investigating the relationships between people and their environment.

## D. Transit Logistical Regression Analysis

Logistical regression analysis was used to investigate the odds of someone reporting at least one transit trip over the two day survey reporting period. Table 33 shows neighborhood design around both home and work are important predictors in the choice to commute by transit. Distance to bus stops or stations also an important predictor of transit use. Over a two-day period the odds of someone reporting a transit trip to work decreased by 16 percent[5] with each 1/4 mile increase in the distance to transit from home and 32 percent with each 1/4 mile increase in the distance to transit from work. Each additional vehicle per household was associated with a 45 percent decrease in the odds of taking transit to work.

5 Odds are determine by subtracting one from the Exp(B) value and multiplying by 100: (Exp(B) -1)*100.

| Independent Variables | B | S.E. | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|
| Income –household, annual3 | -.100 | .042 | 5.740 | 1 | .017 | .905 |
| Vehicles per household | -.589 | .085 | 48.003 | 1 | .000 | .555 |
| Distance to nearest bus stop from home -- categorical4 | -.171 | .059 | 8.500 | 1 | .004 | .843 |
| # of single family parcels at work | -.006 | .002 | 12.433 | 1 | .000 | .994 |
| # of grocery parcels at work | .280 | .110 | 6.449 | 1 | .011 | 1.324 |
| # of office building parcels at work | .039 | .005 | 71.984 | 1 | .000 | 1.039 |
| # of office misc. parcels at work | .057 | .007 | 77.097 | 1 | .000 | 1.059 |
| # of parks parcels at work | .169 | .066 | 6.466 | 1 | .011 | 1.184 |
| # of restaurant parcels at work | -.130 | .029 | 20.680 | 1 | .000 | .878 |
| # of vacant parcels at work | -.032 | .011 | 8.099 | 1 | .004 | .969 |
| Distance to nearest bus stop from work -- categorical5 | -.387 | .165 | 5.494 | 1 | .019 | .679 |
| Quartiles of residential density (units per residential acres) at work | .328 | .067 | 23.767 | 1 | .000 | 1.389 |
| Constant | .280 | .686 | .166 | 1 | .684 | 1.323 |

**Table 33: Take Transit or Not – Logistical Regression (valid N (people, listwise) =2,934)**

The tables below provide descriptives for the variables used in the transit logistical regression model.

| Variables | N (people) | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Did the person make at least one WORK trip by BUS over the two day survey period? | 12,658 | 0 | 1 | 0.033 | 0.179 |
| Income –household, annual6 | 12,658 | 11 | 18 | 16.050 | 1.793 |
| Vehicles per household | 12,658 | 0 | 8 | 2.230 | 1.129 |
| # of single family parcels at work | 3,797 | 0 | 594 | 46.939 | 88.344 |
| # of grocery parcels at work | 3,797 | 0 | 4 | 0.223 | 0.597 |
| # of office building parcels at work | 3,797 | 0 | 58 | 8.807 | 12.950 |
| # of office misc parcels at work | 3,797 | 0 | 63 | 1.552 | 7.107 |
| # of parks parcels at work | 3,797 | 0 | 7 | 0.325 | 0.815 |
| # of restaurant parcels at work | 3,797 | 0 | 18 | 1.508 | 2.461 |
| # of vacant parcels at work | 3,797 | 0 | 151 | 7.831 | 9.732 |

**Table 34: Table 18: Descriptives of Continuous & Categorical Variables Used in Transit Logistical Regression**

| Distance categories to nearest bus stop from home | N | Minimum | Maximum |
|---|---|---|---|
| 1 | 6,638 | .01 | .25 |
| 2 | 2,569 | .26 | .50 |
| 3 | 1,231 | .51 | .75 |
| 4 | 708 | .76 | 1.00 |
| 5 | 2,786 | 1.01 | 20.49 |

**Table 35: Descriptives of Bus Stop Distance Ranges for Home Buffer**

| Distance categories to nearest bus stop from work | N (people) | Minimum (miles) | Maximum (miles) |
|---|---|---|---|
| 1 | 3,892 | .01 | .25 |
| 2 | 464 | .26 | .50 |
| 3 | 210 | .51 | .75 |
| 4 | 93 | .76 | 1.00 |
| 5 | 212 | 1.01 | 14.64 |

**Table 36: Descriptives of Bus Stop Distance Ranges for Work Buffer**

| Quartiles of residential density (units per residential acres) at work | N (people) | Minimum | Maximum |
|---|---|---|---|
| 1 | 1,009 | .00 | .00 |
| 2 | 860 | .01 | 2.41 |
| 3 | 927 | 2.43 | 6.08 |
| 4 | 933 | 6.08 | 98.75 |

**Table 37: Descriptives of Residential Quartiles for Work Buffer**

## E. Transit Linear Regression Analysis

Building off of the origin and destination based partial correlation assessments shown above, linear and logistical regression models were developed to test the effect of parking cost, relative travel time between transit and auto, and land uses at the quarter mile buffer level at the origin and destination ends of work trips on transit use. When viewing the models below, it is important to recall that an environment that supports walking also supports transit use.

Table 38 presents a three-stage multiple regression model predicting the variation in the number of work based transit trips per person in the survey.

**Coefficients** [a]

| | | Unstandardized | | Standardized | | |
|---|---|---|---|---|---|---|
| 1 | (Constant) | .307 | .058 | | 5.264 | .000 |
| | Income - 8 Categories | -.006 | .004 | -.034 | -1.612 | .107 |
| | Total Vehicles | -.052 | .005 | -.202 | -9.622 | .000 |
| 2 | (Constant) | .339 | .056 | | 6.095 | .000 |
| | Income - 8 Categories | -.010 | .003 | -.059 | -2.988 | .003 |
| | Total Vehicles | -.036 | .005 | -.141 | -6.987 | .000 |
| | MIX2 | .054 | .003 | .341 | 17.977 | .000 |
| | # Restuarants h | .006 | .003 | .038 | 1.956 | .051 |
| 3 | (Constant) | .293 | .055 | | 5.375 | .000 |
| | Income - 8 Categories | -.012 | .003 | -.069 | -3.551 | .000 |
| | Total Vehicles | -.030 | .005 | -.116 | -5.815 | .000 |
| | MIX2 | .018 | .006 | .110 | 3.009 | .003 |
| | # Restuarants h | .006 | .003 | .041 | 2.124 | .034 |
| | TAZ-idw-daily parking cost, work-- from MDPARKDA file | 784E-05 | .000 | .081 | 3.247 | .001 |
| | ED_TOT | 102E-05 | .000 | .091 | 4.844 | .000 |
| | Office Building Rent Area w | 847E-08 | .000 | .217 | 6.173 | .000 |
| | Net Residential Density w | .003 | .001 | .082 | 4.108 | .000 |

a.

**Table 38: Linear Regression Results - Proportion of Per Capita Work Trips on Transit**

Increases in income and total number of household vehicles are associated with reduced transit usage. These two variables explained .046 percent of the variation in per capita transit use. The addition of land use mix (increased mix means more evenly distributed rentable area between retail, residential, entertainment, and office uses) and the number of restaurants and taverns at the place of residence increased the explained variation in the proportion of transit trips for work to 16.3 percent. Finally, the addition of workplace variables including daily parking cost, employment density, rentable office space and residential density increased the explained variation in the proportion of trips on transit to just over 20 percent. Each of the land use measures and parking costs were positively associated with transit use, whereas the two demographic factors, income and number of vehicles, were inversely associated with transit use. Additional research was done to assess the likelihood of taking transit to work based on demographic and urban form factors. The results of this logistical regression model are presented in Table 39.

**Variables in the Equation**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Step 1[a] | TOTVEH | -.519 | .077 | 45.283 | 1 | .000 | .595 |
| | INCOME8 | -.101 | .040 | 6.383 | 1 | .012 | .904 |
| | NETDENSW | .014 | .005 | 6.541 | 1 | .011 | 1.014 |
| | OBRAREAW | .000 | .000 | 5.815 | 1 | .016 | 1.000 |
| | EBUSSTOP | .056 | .007 | 56.578 | 1 | .000 | 1.058 |
| | ED_TOT | .000 | .000 | 26.900 | 1 | .000 | 1.000 |
| | PARKSW | .117 | .066 | 3.145 | 1 | .076 | 1.124 |
| | DPARKW | .001 | .000 | 24.905 | 1 | .000 | 1.001 |
| | Constant | -.739 | .603 | 1.502 | 1 | .220 | .477 |

a.

**Table 39: Logistical Regression Results - Proportion of Per Capita Work Trips on Transit**

Results of this model can be interpreted into specific odds of taking transit based on the numbers of vehicles or income level per household. In this model, only urban form factors at the place of employment were found to be significant in predicting the likelihood of taking transit for work purposes. Net residential density, rentable area for office use, number of bus stops per square kilometer, employment density, number of parks, and the daily cost of parking at the place of employment were each found to be significant predictors of transit use.

## IV. Land Use and Household Vehicle Miles / Vehicle Hours Traveled

Vehicle miles traveled (VMT) and vehicle hours traveled (VHT) are two conventional measures used by transportation planning agencies in evaluating the performance of the regional road network. While used similarly, these measures differ distinctly in their ability to capture the effects of transportation improvements. In this study VMT and VHT are measured at the household level, and corresponding measures of urban form are assessed at the place of residence in the following analyses.

VMT measures the number of vehicle miles generated by a person, a household, or a region and relates to the relative accessibility of trip destinations: the closer the distance between complementary destination attractions, such as home and work, the lower the amount of VMT that needs to be generated. Reductions in VMT can be theoretically achieved by mixing complementary land uses together, increasing the directness of routes, and encouraging switches to alternative modes, such as transit, bicycling and walking. Carpooling likewise can have a significant effect on VMT. Since additional travelers are included in a single vehicle trip, a two-person carpool can theoretically reduce VMT by up to 50 percent over the VMT that would have been generated had these individuals each traveled in their own vehicle (Ewing 1995).

While VMT is a useful measure of system performance, it fails to account for the amount of congestion on a road network. Assuming that an individual's journey to work is ten miles, the amount of time it takes to travel this distance can vary significantly depending on the level of roadway congestion. In free-flowing conditions on the Interstate, a trip could be accomplished in ten minutes. On congested local routes, the same trip could easily take 30 minutes or more.

Because of the inability of VMT to capture the effects of network congestion, VHT is often used as a complementary measure to describe vehicle travel. A second advantage of VHT over VMT is its ability to better capture the experiential aspect of travel – people typically evaluate their travel in terms of time, rather than distance.

Correspondingly, VHT may be a useful measure for quantifying a region's quality of life. While some individuals may enjoy traveling for its own sake, it is reasonably safe to assume that, on the whole, most people would prefer to have the time available for meaningful activities, such as spending time with their families or pursuing recreational activities. The longer the amount of time needed to access a destination, the less the amount of time there is actually available to accomplish those meaningful activities.

To understand the role that land use mixing near households can play on VMT and VHT reduction, the research team examined the effects of land use mixing on these variables at two levels of analysis – at a quarter-mile distance from survey households, which corresponds to conventional notions of "comfortable" walking distance, and secondly, at a two mile distance from survey households, which translates roughly to a five minute drive.

## A. Vehicle Miles Traveled

The distribution of household VMT is shown in Figure 33 below. The typical survey household generated 63 vehicle miles of travel[6] on an average day, based on estimated travel distances. There was a wide range of values for household VMT, with two thirds of households in the sample generating between 7 and 119 miles of travel over the two-day survey period (a standard deviation of 56 miles).

6 Vehicle travel does not include travel by the following modes provided by survey participants walking, bicycle, ferry, other, don't know.

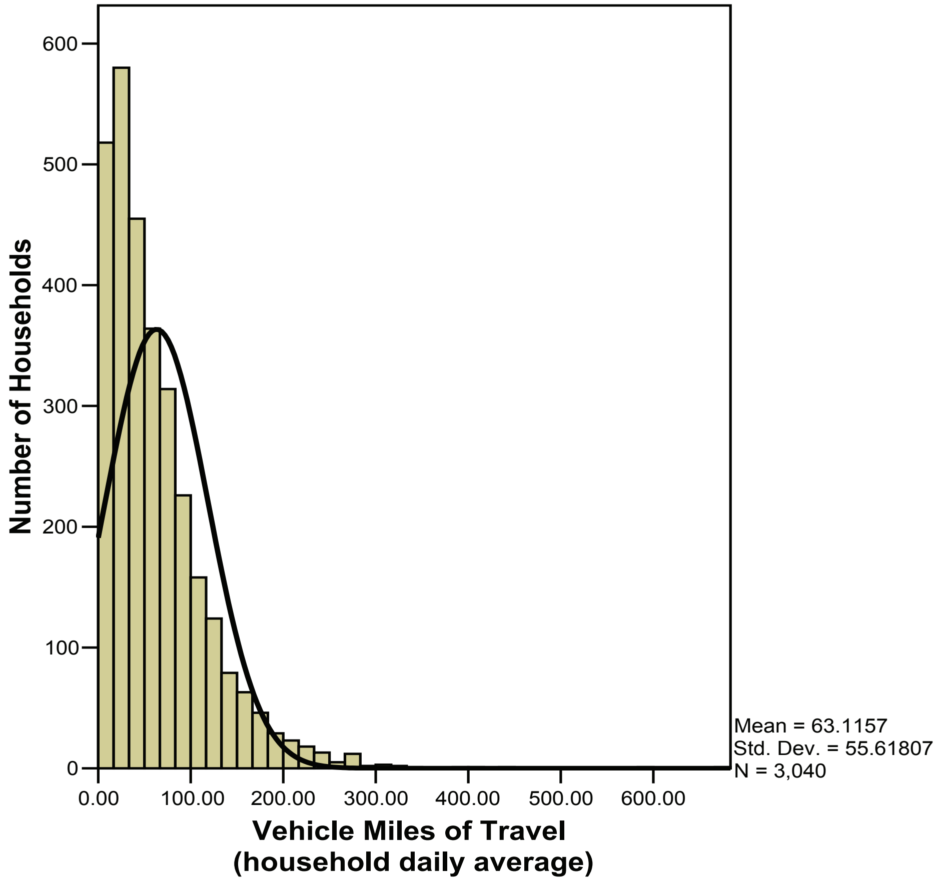


**Figure 33: Household Vehicle Miles of Travel (household, daily average, estimated)**

The majority of households generated VMT at or below the average value, with a smaller number of households producing much larger amounts. We suspected that this skewed distribution of VMT reflected the spatial distribution of the population as a whole – the majority of households in King County are clustered near core areas such as Seattle and Bellevue, with population densities tapering off outside these areas. Since households living near core areas have access to a greater number of destinations, they generate lower VMT since shorter travel distances are required to accomplish household trip purposes. For the subsequent statistical analysis, the natural log of VMT was computed in order to normalize this distribution.

## 1. Correlations between VMT and Land Use Mixture near the Household

As a preliminary step to understanding the influence that land use mixing can have on household VMT, the research team examined the correlation between VMT and two urban form variables at the quarter-mile buffer level – net residential density and street connectivity – when controlling for household size, income and the number of household vehicles. Table 40 shows these results.

| Design Measure | Correlation Coefficient |
|---|---|
| *Net Residential Density* | - 0.0468 (P=0.019) |
| *Street Connectivity* | - 0.0534 (P=0.007) |
| *Sidewalk Density* | - 0.0104 (P=0.600) |

**Table 40: Correlations between VMT and Neighborhood-Design Variables**

(Controlling for Household Size, Income and # of Household Vehicles)

Both variables were negatively correlated with household VMT, meaning that as residential density and street connectivity increases, household VMT declines. Both were significantly correlated - however, their correlation results were weak – -0.0468 and -0.0534, respectively.

Since walking can substitute for automobile travel at distances of a quarter mile or less, the research team wanted to control for any VMT reduction which might be associated with mode substitution in walkable areas. As was shown earlier in the walking analysis, increased street connectivity was somewhat related to increased walking rates. Therefore, when examining the relationships between VMT and the land uses within a quarter mile of the respondents' households, it was necessary to control for the effects of this connectivity. As with earlier steps, the correlation analysis here also controlled for demographics, including household size, household income, and the number of automobiles available.

Finally, the analysis again examined the three different approaches to measurement of land use described earlier: the number of unique attractions by each use, the total rentable floor space by use, and the total parcel area of each use within a ¼ mile of each household. Table 41 shows these initial correlation results.

| Land Use Type | Number of Attractions | Rentable Building Area | Total Parcel Area |
|---|---|---|---|
| *Civic* | - 0.0928 (P=0.000) | - 0.0940 (P=0.000) | - 0.0420 (P=0.032) |
| *Convenience Stores* | - 0.0582 (P=0.003) | - 0.0443 (P=0.024) | - 0.0509 (P=0.010) |
| *Doctor-Dentist Offices* | - 0.0896 (P=0.000) | - 0.0949 (P=0.000) | - 0.0448 (P=0.022) |
| *Educational* | - 0.0958 (P=0.000) | - 0.043 (P=0.027) | - 0.0800 (P=0.000) |
| *Entertainment* | - 0.0309 (P=0.115) | - 0.0239 (P=0.224) | - 0.0018 (P=0.926) |
| *Fast Food Restuarants* | - 0.0474 (P=0.016) | - 0.0451 (P=0.022) | - 0.0452 (P=0.021) |
| *Grocery Stores* | - 0.0905 (P=0.000) | - 0.0865 (P=0.000) | - 0.0725 (P=0.000) |
| *High-Tech Industry* | - 0.0462 (P=0.019) | - 0.0475 (P=0.015) | - 0.0639 (P=0.001) |
| *Museums* | - 0.0060 (P=0.761) | - 0.0081 (P=0.681) | - 0.0257 (P=0.190) |
| *Office Buildings* | - 0.0778 (P=0.000) | - 0.0705 (P=0.000) | - 0.0636 (P=0.001) |
| *Office Parks* | - 0.0142 (P=0.469) | - 0.0167 (P=0.395) | 0.0015 (P=0.940) |
| *Office - Miscellaneous* | - 0.0303 (P=0.123) | - 0.0301 (P=0.126) | - 0.0231 (P=0.102) |
| *Parks* | - 0.0580 (P=0.003) | NA | - 0.0564 (P=0.004) |
| *Playgrounds* | - 0.0153 (P=0.435) | NA | - 0.0038 (P=0.846) |
| *Recreational* | 0.0124 (P=0.528) | - 0.0260 (P=0.186) | 0.0395 (P=0.044) |
| *Restuarants and Taverns* | - 0.0553 (P=0.005) | - 0.0530 (P=0.007) | - 0.0482 (P=0.014) |
| *Retail - Large* | - 0.0676 (P=0.001) | - 0.0535 (P=0.006) | - 0.0458 (P=0.020) |
| *Retail - Neighborhood* | - 0.0663 (P=0.001) | - 0.0747 (P=0.000) | - 0.0497 (P=0.011) |
| *Vacant Parcels* | - 0.0266 (P=0.175) | NA | - 0.0302 (P=0.124) |

**Table 41: Correlations between Land Use Measures at the Household End and Household VMT**

(Controlling for Household Size, # of Household Vehicles, and Street Connectivity)

When examined independently of one another, the land uses with the strongest significant correlations to reductions in household VMT were:

- The Number of Educational Facilities
- The Number of Grocery Stores
- The Floor Space of Civic Uses
- The Rentable Floor Space of Doctor and Dentist Offices
- The Rentable Floor Space of Neighborhood Retail Attractions
- The Number of Large Retail Attractions
- The Number of Convenience Stores
- The Number of Fast Food Restaurants

While individual uses appear to be significant predictors of travel distance, these measures fail to account for the interplay between the uses themselves. The combination of a variety of uses in one area most likely influences the correlation between individual uses and household VMT. As expected, most of the variables were negatively correlated with household VMT. Of these variables, the most strongly correlated land uses proved to be the number of educational facilities, the number of grocery stores, the rentable area of civic space, the rentable area of doctor and dentist offices, the number of commercial office buildings, the number of large retail attractions, and the rentable area of neighborhood retail.

Taken independently, however, none of the variables had a very strong relationship with reductions in household VMT – indeed, the most strongly correlated variable, the number of educational facilities, had a partial correlation of only 0.0958. While their individual results may not have been strong, we expected that collectively, land use mixing should show a moderate to moderately strong correlation with reduced vehicle travel demand.

## 2. ANOVA analysis of VMT controlling for demographics

Based on an analysis of variance (ANOVA) statistically significant differences in VMT across urban form quartiles at the one kilometer buffer level were found, even when controlling for demographics, vehicle and transit availability (Table 42).

The greatest differences in VMT were observed across levels of intersection density, where mean VMT was 34 miles per person in the least and 25 miles in the most connected environments of King County. This represents 26% fewer vehicle miles of travel for residents who live in communities that have the most interconnected street networks in the county.

| Urban Form Factors | VMT (miles, per capita daily estimated marginal means) | | | | Statistics across urban form quartiles (individually considered), controlling for gender, income, age, education, total household vehicles, distance to nearest bus stop | | |
|---|---|---|---|---|---|---|---|
| | Quartiles of Urban Form Variables7 | | | | | | |
| | 1 | 2 | 3 | 4 | F-value | Signif. | Partial-Eta squared |
| Retail Floor Area | 30.16 | 30.48 | 30.50 | 25.57 | 15.223 | 0.000 | 0.008 |
| Intersection Density | 34.03 | 28.83 | 30.01 | 25.46 | 21.528 | 0.000 | 0.011 |
| Residential Density | 29.77 | 29.14 | 28.13 | 27.17 | 3.135 | 0.024 | 0.002 |
| Mixed Use | 32.26 | 30.38 | 27.94 | 27.15 | 9.265 | 0.000 | 0.005 |

**Table 42: VMT Across Urban Form (ANOVA analysis)**

Table 43 indicates the values ranges for each variable's quartiles, as used in the ANOVA analysis above.

| Urban Form Factors (1km road-network-based household buffer) | Quartiles of Urban Form Variables | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | |
| | Min. | Max. | Min. | Max. | Min. | Max. | Min. | Max. |
| Retail Floor Area | 0.00 | 0.00 | 0.00 | 0.14 | 0.15 | 0.33 | 0.33 | 3.53 |
| Intersection Density (# per square kilometer) | 0.00 | 27.56 | 27.78 | 43.35 | 43.37 | 58.71 | 58.75 | 158.93 |
| Residential Density (housing units per net residential acre) | 0.95 | 2.07 | 2.07 | 3.02 | 3.02 | 4.85 | 4.85 | 126.84 |
| Mixed Use | -3.25 | 0.20 | 0.20 | 0.28 | 0.28 | 0.36 | 0.36 | 0.84 |

**Table 43: Quartile Ranges of Urban Form Variables Used in VMT ANOVA**

## 3. Regression analysis of VMT

To test the effect of changes in variables on household VMT, the research team developed a multivariate linear regression model that tested all of the significantly correlated variables. Table 44 illustrates the results for the "best fit" model.

| Variable | Beta Coefficients | Significance |
|---|---|---|
| Household Size | 0.178 | 0.000 |
| Household Income | 0.154 | 0.000 |
| Household Vehicles | 0.190 | 0.000 |
| # Convenience Stores | -0.037 | 0.048 |
| # Educational Facilities | -0.071 | 0.000 |
| # Parks | -0.042 | 0.024 |
| # Groceries | -0.067 | 0.000 |

Dependent Variable: Natural Log of VMT

R2 = 0.195
Number of Observations = 2462

**Table 44: Regression Model for Household Vehicle Miles Traveled**

## a) Model Results

The best-fit model explained 19.5% of the variance in rates of vehicle miles of travel among survey households. Of the variables entering into the model, the household-level control variables, which included household size, income, and number of vehicles, had moderate positive relationships with household level VMT. In other words, as the household size, income, or number of vehicles increases, so does household travel demand. This finding is unsurprising. More individuals create higher overall travel demand as these additional household members go about their personal business; higher incomes or a greater number of vehicles translates into increased ability to travel by a personal vehicle as well.

Several land use variables at the quarter mile buffer level were also significant in the model with negative beta coefficients, indicating that they were responsible for decreasing household VMT. The number of grocery stores, educational facilities, parks and convenience stores all accounted for weak, but significant, decreases in VMT. The weakness of their influence is not surprising given that these trip purposes account for only a small share of the number of trips generated by a household. Moreover, since these trips are typically shorter than work trips, dramatic reductions in VMT resulting from the presence of these uses would have been unlikely. Nonetheless, their presence in the model does account for statistically significant reductions in VMT, and in areas with concerns about diminishing air quality and increasing congestion, their influence may be important.

### (1) On Educational Facilities

Because public school children are typically assigned to the school closest to their home, the presence of nearby educational facilities appears to reduce household VMT by reducing the distance parents need to travel to drop off or pick up their child. Further, because these facilities are within a quarter-mile of the survey households, it is equally as likely that the drive trips are replaced entirely by walk trips – in other words, rather than needing to be driven to school, children have the ability to walk or bike, eliminating an automobile trip completely.

#### (2) On Neighborhood Grocery and Convenience Stores

Both groceries and convenience stores are household-sustaining uses, and their significant entry into the model is unsurprising. While the frequency of trips to these destinations are typically sensitive to distance (closer stores are visited more often), closer proximity of these uses to household locations will mean that shopping trips are generally shorter.

#### (3) On Parks

That parks should enter significantly to the model is surprising. We suspect that the influence of parks on household VMT is in fact a proxy effect – the presence of nearby parks may encourage people to shift modes overall from driving to walking or bicycling for some trip purposes.

## B. Vehicle Hours Traveled

The typical survey household generated two hours of travel per day[7] on an average day, based on estimated travel times. There was a relatively wide distribution in the total hours of household travel, however, with two-thirds of houses generating between 0.3 and 3.7 hours of vehicle travel over an average period (a standard deviation of 1.7 hours). The distribution is shown in Figure 34.

7 Vehicle travel does not include travel by the following mode categories from which survey participants could choose: walking, bicycle, ferry, other, don't know.

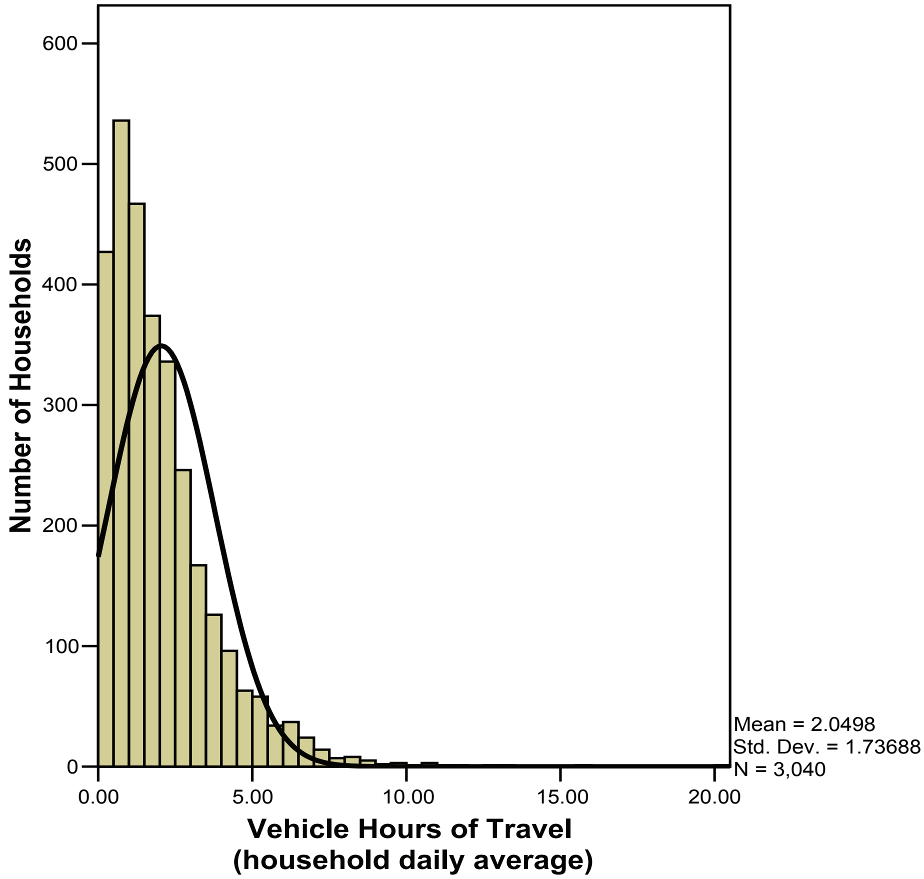


**Figure 34: Household Vehicle Hours of Travel (household, daily average, estimated)**

## 1. VHT and Land Use Mixture near the Household

The natural log of VHT was used to normalize the distribution of values in the subsequent analysis. As was the case with VMT analysis, household VHT was first tested against net residential density and street connectivity. Mixed use is assessed separately in a subsequent analysis. Table 45 lists the partial correlation coefficient for these variables when controlling for the effects of household size, household income and the total number of household vehicles.

| Design Measure | Correlation Coefficient |
|---|---|
| *Net Residential Density* | 0.0214 (P=0.294) |
| *Street Connectivity* | - 0.0272 (P=0.182) |
| *Sidewalk Density* | - 0.0006 (P=0.978) |

**Table 45: Correlations between VHT & Neighborhood-Design Variables**

(Controlling for Household Size, Income, and # of Household Vehicles)

Neither urban form variable proved to be significantly correlated with household VHT. To better understand the relationship between individual land uses and household VHT, the team correlated the individual land uses with VHT while controlling for the effects resulting from household level variables: household size, income and the number of automobiles available. Given the lack of significant correlations, no urban form variable controls were included in this correlation analysis. The same three dimensions of land use were employed, as in earlier analyses. Table 46 shows these initial correlation results.

| Land Use Type | Number of Attractions | Rentable Building Area | Total Parcel Area |
|---|---|---|---|
| *Civic* | - 0.0399 (P=0.047) | - 0.0432 (P=0.032) | - 0.0170 (P=0.398) |
| *Convenience Stores* | - 0.0303 (P=0.132) | - 0.0231 (P=0.251) | - 0.0261 (P=0.196) |
| *Doctor-Dentist Offices* | - 0.0538 (P=0.008) | - 0.0386 (P=0.055) | - 0.0356 (P=0.077) |
| *Educational* | - 0.0494 (P=0.014) | - 0.0193 (P=0.338) | - 0.0433 (P=0.032) |
| *Entertainment* | - 0.0130 (P=0.520) | - 0.0184 (P=0.361) | 0.0121 (P=0.548) |
| *Fast Food Restuarants* | - 0.0520 (P=0.010) | - 0.0484 (P=0.016) | - 0.0474 (P=0.019) |
| *Grocery Stores* | - 0.0637 (P=0.002) | - 0.0596 (P=0.003) | - 0.0501 (P=0.013) |
| *High-Tech Industry* | - 0.0130 (P=0.520) | - 0.0348 (P=0.084) | - 0.0316 (P=0.116) |
| *Museums* | 0.0156 (P=0.440) | 0.0034 (P=0.867) | 0.0185 (P=0.359) |
| *Office Buildings* | - 0.0446 (P=0.027) | - 0.0309 (P=0.125) | - 0.0312 (P=0.122) |
| *Office Parks* | - 0.0181 (P=0.369) | - 0.0184 (P=0.362) | - 0.0081 (P=0.687) |
| *Office - Miscellaneous* | - 0.0222 (P=0.270) | - 0.0222 (P=0.269) | - 0.0247 (P=0.221) |
| *Parks* | - 0.0364 (P=0.071) | NA | - 0.0368 (P=0.068) |
| *Playgrounds* | - 0.0007 (P=0.974) | NA | - 0.0250 (P=0.214) |
| *Recreational* | 0.0042 (P=0.833) | 0.0182 (P=0.367) | - 0.0114 (P=0.570) |
| *Restuarants and Taverns* | - 0.0358 (P=0.075) | - 0.0348 (P=0.084) | - 0.0296 (P=0.141) |
| *Retail - Large* | - 0.0239 (P=0.235) | - 0.0113 (P=0.575) | - 0.0239 (P=0.308) |
| *Retail - Neighborhood* | - 0.0394 (P=0.051) | - 0.0434 (P=0.031) | - 0.0394 (P=0.063) |
| *Vacant Parcels* | - 0.0087 (P=0.665) | NA | - 0.0009 (P=0.962) |

**Table 46: Correlations between Land Use Measures & Household VHT**

(Controlling for Household Size, Income, # of Household Vehicles, and Street Connectivity)

When examined independently of one another, the land uses with the strongest significant correlations to reductions in household VHT were:

- Number of Grocery Stores
- Number of Doctor and Dentist Offices
- Number of Educational Facilities
- Number of Fast Food Restaurants

## 2. Regression Analysis of VHT

Once the correlations between land uses and household VHT were identified, a regression model that would best explain household VHT was developed. Table 47 shows the results of the 'best fit' model.

| Variable | Beta Coefficients | Significance |
|---|---|---|
| Household Size | 0.255 | 0.000 |
| Household Income | 0.135 | 0.000 |
| Household Vehicles | 0.230 | 0.000 |
| Net Residential Density | 0.052 | 0.010 |
| # Groceries | -0.057 | 0.003 |
| # Fast Food Restaurants | -0.042 | 0.023 |
| # Educational Facilities | -0.040 | 0.032 |

Dependent Variable: VHT

R2 = 0.240
Number of Observations = 2424
F Statistic = 108.71

**Table 47: Regression Model for Household Vehicle Hours Traveled**

The best-fit model explained 24% of the variance in rates of vehicle hours of travel among survey households. As with VMT, household VHT increases as household size, income, or number of vehicles increases. The urban form measure of net residential density proved to be positively, but weakly, correlated with VHT. This is undoubtedly due to the fact that more households generate a greater number of trips, increasing local congestion and decreasing travel speeds. This decrease in travel speed lengthens the amount of time necessary to access a destination, even if the destination is relatively close by. While this may at first surprise those advocating higher developmental densities, it is important to recognize that increased density also brings increased local traffic congestion. This is not necessarily a bad thing. Although higher density increases travel time, it also supports the land use mixture that reduces travel distance and encourages non-motorized modes such as walking and biking.

The three land use categories entering significantly and negatively into the model were the number of grocery stores, educational facilities and fast food restaurants within a quarter mile of the household's location. All of the variables had relatively weak beta coefficients, however, ranging from -0.04 to -0.057. The reduction in household VHT due to the proximity of educational facilities appears to be due to the fact that parents can minimize additional trip distances when dropping children off at school, or that school vehicle trips are eliminated entirely because of a child's ability to walk to school.

That the proximity of grocery stores did not show a stronger relationship with reductions in household VHT is at first surprising since grocery trips are necessary to sustain a household, and one would have expected the presence of nearby groceries to reduce or eliminate vehicle trips altogether. A closer examination of the characteristics of grocery trips appears to explain the weakness of the measure, however. The frequency of grocery trips tend to be sensitive to distance. Where grocery stores are not conveniently located near one's household, we suspect that individuals needing to travel to these locations make fewer trips, but purchase a greater quantity of items, thereby increasing the period of time before they are required to travel to the grocery again. Conversely, individuals with grocery stores near their homes tend to make more trips, picking up items as they are needed.

Increasing the number of fast food restaurants within the quarter mile household buffer significantly decreases the amount of VHT generated by a household. That there should be any positive benefit associated with the presence of fast food restaurants seems to fly in the face of the conventional planning concept of a "livable" neighborhood. Nevertheless, to the extent that lowered household VHT is an important feature of more livable neighborhoods, it appears that fast food restaurants may not be entirely undesirable.

# V. Relationships between Land Use, Urban Form and Emissions

As described earlier in the methodology, emissions for all trips reported by King County residents in the 1999 Puget Sound Regional Household Activity Survey were modeled using the Puget Sound Regional Travel Demand Forecasting Model and the US EPA emissions modeling software, MOBILE 6.2. Emissions were first calculated at the trip component level, then aggregated to the trip level and summed for each person's and household's two days of travel.

## A. Description of Modeled Trip Characteristics

Trips which use the freeways make up 40% of trips using the roadways[8]. Most trips use a combination of arterial and/or local roads. As expected, trips over the freeway system were substantially longer than those making use of the other surface streets. Table 48 shows the substantial difference in average trip length between the two groups of trips (13.6 miles versus 3.3 miles). The mean total distance for all trips by all road using modes was 7.5 miles.

| Trip route includes: | % of Trip Mean Distance (miles) | | | | Total trip length |
|---|---|---|---|---|---|
| | N (trips) | Freeway | Arterial | Local | |
| Freeway and/or arterial and/or local streets | 20,816 | 59.4% | 36.5% | 4.1% | 13.6 |
| Only arterial and/or local streets | 30,738 | 0.0% | 86.5% | 13.5% | 3.3 |
| All trips | 51,554 | 43.6% | 49.8% | 6.6% | 7.5 |

Note: does not include walk, ferry, other, don't know/refused modes.

**Table 48: Proportion of on-road trip distance allocated to freeways, arterials and local roads**

As documented in Chapter III, emissions were estimated based on roadway characteristics. These data show that the majority of distance was travelled on arterials.

8 Modes which use the roadway do not include walk, ferry, other, don't know/refused.

## B. Criteria Pollutants and Urban Form

All trips reported by King County households in the Puget Sound Household Activity Survey were modeled at the trip component level. Following this, emissions factors for the three criteria air contaminants (CACs) – VOC, CO and NOx – were applied, and emissions data were aggregated at the mode, trip and person level. A summary of emissions by trip and mode are provided in Table 49 and Table 50.

| | Number of Trips | Min (g) | Max (g) | Mean (g) | S.D. |
|---|---|---|---|---|---|
| VOC | 56,032 | 0 | 60.71 | 3.07 | 3.02 |
| $NO_x$ | 56,032 | 0 | 148.53 | 6.01 | 7.23 |
| CO | 56,032 | 0 | 1272.76 | 58.14 | 65.06 |

**Table 49: Trip Level and Two Day Total Emissions of Criteria Air Contaminants among Survey Participants**

Among King County participants in the survey, the average trip produced 3.07g of VOC, 6.01g of $NO_x$, and 58.14g of CO. Over the two-day survey period in 1999, travel within King County by survey participants resulted in total emissions of approximately 172kg VOC, 337kg $NO_x$, and 3,258kg CO.

| Mode | Number of Trips | Mean VOC (grams) | Mean $NO_x$ (grams) | Mean CO (grams) |
|---|---|---|---|---|
| Auto driver | 34,822 | 4.03 | 7.90 | 76.92 |
| Auto passenger | 12,156 | 2.28 | 4.21 | 41.91 |
| Walk | 4,114 | 0.00 | 0.00 | 0.00 |
| Bus (Public Transit) | 1,960 | 0.38 | 1.69 | 9.24 |
| School bus | 1,104 | 0.65 | 2.71 | 14.07 |
| Bicycle | 700 | 0.00 | 0.00 | 0.00 |
| Carpool passenger | 507 | 1.99 | 4.00 | 39.02 |
| Ferry/Passenger boat | 210 | 0.00 | 0.00 | 0.00 |
| Vanpool passenger | 101 | 1.20 | 2.95 | 27.04 |
| Carpool driver | 97 | 2.02 | 4.47 | 40.56 |
| Motorcycle, moped | 50 | 22.95 | 9.12 | 109.60 |
| Taxi/paid limo | 31 | 5.40 | 16.35 | 126.29 |
| Vanpool driver | 26 | 0.79 | 1.73 | 16.14 |

**Table 50: Mean Trip Level Emissions by Travel Mode**

The vast majority of respondent trips were taken by automobile, and this mode was also responsible, for the most part, for the highest per trip rates of emissions for the three pollutants measured. Exceptions include high levels of VOC emissions for motorcycles and mopeds, and high levels of emissions overall for taxis and limousines. Clearly, however, automobiles are the greatest contributor to King County trip level emissions, which suggests that any land use and urban form measures which influence VMT and VHT will also influence overall trip emission rates.

A few issues revealed in the table above suggest caution in the interpretation of results. Of particular concern are the emission results for school bus and bus transit trips. Emissions for these trips are sensitive to assumptions regarding occupancy and average speed. Off-peak occupancies were assumed to be 20 persons for both bus modes, and peak occupancies were assumed to be 50. Also, travel speeds for both transit and school buses were assumed to be the same as the modeled link average speed. Reality may show that speeds for these modes are actually below average; overestimation of these speeds in the model could result in elevated estimations of NOx emissions for these two modes.

## 1. Relationships between CAC emissions and land use and urban form near the household and place of employment.

Once person-level data on trip related CAC emissions were assembled, analyses were conducted to identify relationships between these emissions resulting from trips to work and land use and urban form characteristics at the household and employment locations. At present, the region is more focused on strategies to reduce VOCs, therefore the results presented below are for VOC emissions only. Unlike the partial correlations employed in previous analyses detailed in this report, the initial examination of the relationships between CAC emissions, land use and urban form was conducted using ANOVA. The following sections graphically display emission levels in relation to urban form and land use variables, and present the results of ANOVA analysis of these relationships. Note that in each analysis the difference in at least one pair of mean values is statistically significant. The data set used for these analyses consists of average daily emission totals per person from all polluting trips (all purposes) made by those people who both live and work in King County.

### a) Intersection Density at the household location

The research team hypothesized that, since intersection density showed a significant correlation with walking trip rates, this urban form variable should also show a relationship with person level trip emissions. As Figure 35 shows that mean VOC emissions decrease with increasing intersection density at the one kilometer household buffer level[9]. As shown in Table 51, the ANOVA results, controlling for gender, income, age, education level (bachelors degree or not), and total number of household vehicles, indicate that the differences in mean person level trip emissions at different intersection densities are not random (significance: $p<0.001$). Households with fewer than 36 intersections per square kilometer generated approximately 17.5 grams of VOCs per person per day, whereas those with more than 69 intersections per square kilometer generated about 14.4 grams of VOCs per person per day. Similarly, mean emissions of NOx declined from 29 to 23 grams per person per day, a 21 percent reduction, between residents of the least to the most connected environments[10].

9 This result is based on the sample population of those people who live AND work in King County.

10 This result, unlike the others, is based on people who live in King County, but who could work anywhere in the four county study area.

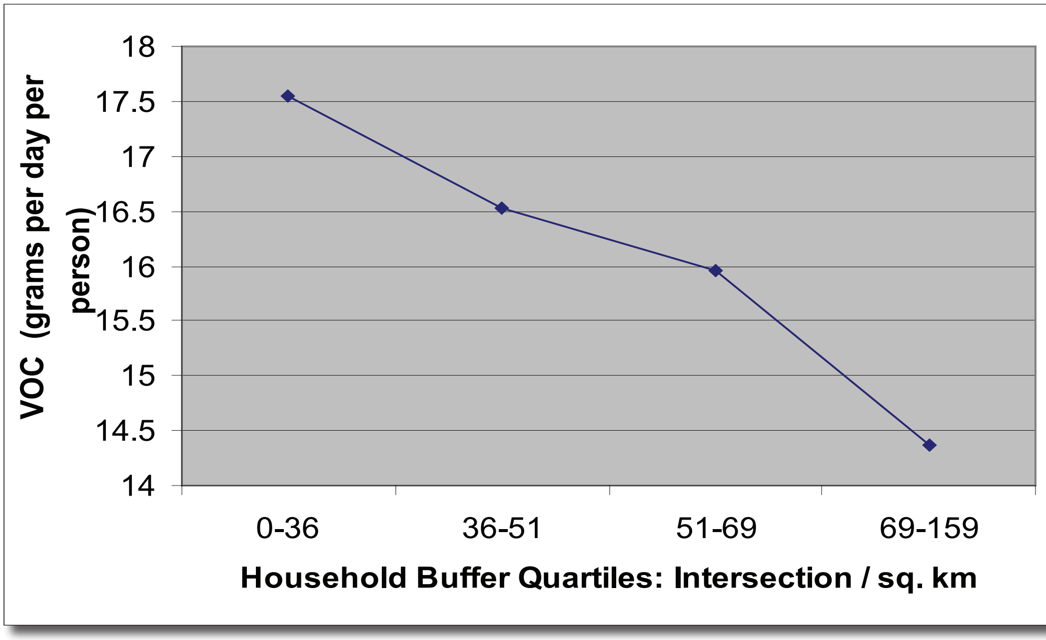


**Figure 35: VOC Emissions and Intersection Density at 1km Household Buffer**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 11519.08958 | 8 | 1,439.886 | 19.714 | 0.000 |
| Intercept | 751.1779394 | 1 | 751.178 | 10.285 | 0.001 |
| Gender | 635.3727715 | 1 | 635.373 | 8.699 | 0.003 |
| Income (annual, household) | 1044.209552 | 1 | 1,044.210 | 14.297 | 0.000 |
| Age | 320.2551342 | 1 | 320.255 | 4.385 | 0.036 |
| Education level | 520.5441024 | 1 | 520.544 | 7.127 | 0.008 |
| Vehicle per household | 1855.267341 | 1 | 1,855.267 | 25.401 | 0.000 |
| Intersection density quartiles (home location, 1km buffer) | 2952.679137 | 3 | 984.226 | 13.476 | 0.000 |
| Error | 179527.8565 | 2458 | 73.038 | | |
| Total | 830455.7106 | 2467 | | | |

**Table 51: VOC (gram per day per person) ANOVA results**

### (1) Number of Neighborhood Retail Attractions

Next, the research team examined the relationship between person-level trip emissions and the total floor area of neighborhood retail attractions.[11] As Figure 36 shows, person level VOC emissions decreased with increasing floor area totals of neighborhood retail attractions at the employment location, a finding confirmed to be significant by an ANOVA analysis (Table 52). This analysis suggests that about 150,000 square feet of retail use within one kilometer of where people work is required before significant VOC reductions are observed. For work environments, the amount of retail was the best urban form predictor of VOC generation.

11 A neighborhood retail attraction is considered to be a single building less than 100,000 square feet in floor area.

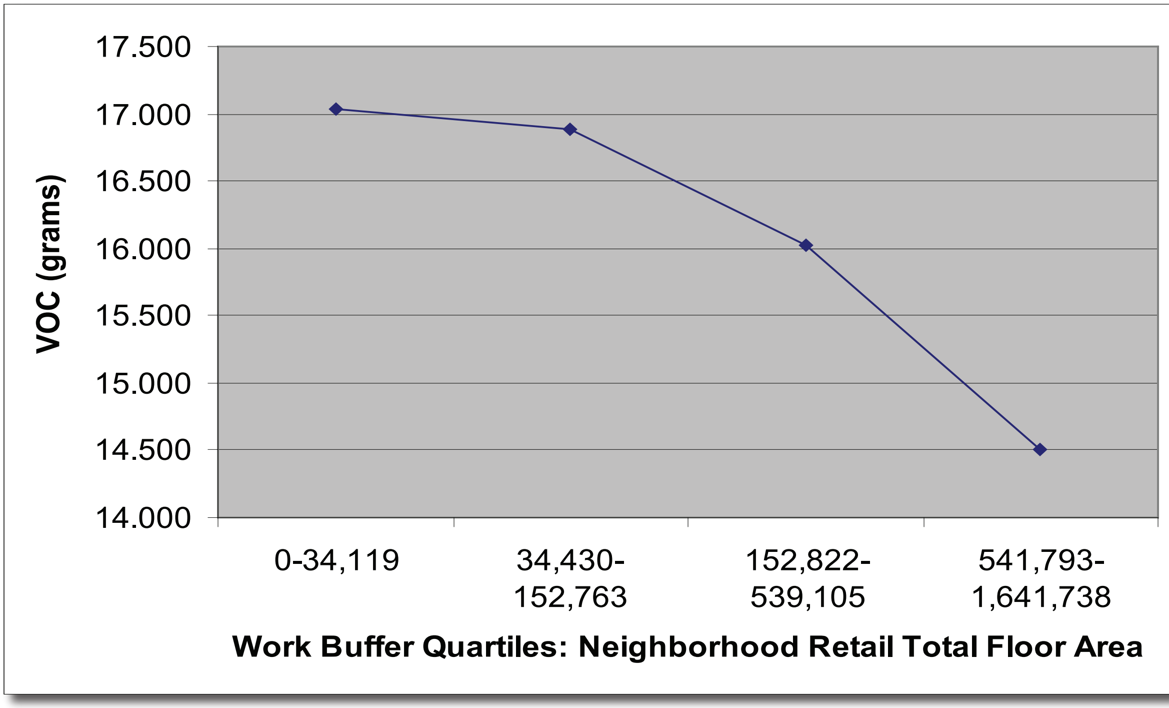


Figure 36: VOC Emissions and Number of Neighborhood Retail Attractions within 1km Work Buffer

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Corrected Model | 10796.81 | 7 | 1,542.401 | 20.973 | 0.000 |
| Intercept | 403.4459 | 1 | 403.446 | 5.486 | 0.019 |
| Gender | 622.1632 | 1 | 622.163 | 8.460 | 0.004 |
| Income (annual, household) | 1753.715 | 1 | 1,753.715 | 23.846 | 0.000 |
| Age | 469.7528 | 1 | 469.753 | 6.387 | 0.012 |
| Vehicle per household | 2163.078 | 1 | 2,163.078 | 29.412 | 0.000 |
| Neighborhood retail floor area quartiles (work location, 1km buffer) | 2394.208 | 3 | 798.069 | 10.852 | 0.000 |
| Error | 178856.5 | 2432 | 73.543 | | |
| Total | 823697.9 | 2440 | | | |

Table 52: VOC (gram per day per person) ANOVA results

## 2. CAC Regression Analysis

After confirming individual relationships between urban form and land use variables and person-level trip emissions, the research team developed a multivariate linear regression model to further investigate the relationship between independent land use and urban form variables and person-level trip emissions, while controlling for household vehicle ownership and income. The dependent emissions variables were converted to log values to facilitate their analysis. The particular measure chosen to represent the independent variables (number of attractions by use, rentable area by use, or total parcel area by use) were selected based on their performance in previous analyses. 'Best fit' regression models for both the employment and home locations for VOC and $NO_x$ emissions are presented and discussed below.

### a) Employment Location Analysis

Table 53 and Table 54 show the regression results for VOC and NOX emissions. For the most part, land uses were entered into the employment location models using rentable area measures.

| Variable | Beta Coefficient | Significance |
|---|---|---|
| Total number of household vehicles | 0.072 | 0.000 |
| Income – 8 groups | 0.039 | 0.000 |
| Office building rentable area | -1.360E-08 | 0.000 |
| Office miscellaneous rentable area | -1.501E-07 | 0.000 |
| Neighborhood retail rentable area | -2.454E-07 | 0.000 |
| Ratio of dwelling units to neighborhood retail attractions | -9.149E-05 | 0.003 |
| Vacant parcel area | 1.543E-07 | 0.000 |
| Constant | 0.641 | 0.000 |

**Table 53: Regression of household demographics, land use and urban form (quarter mile buffer level) against person-level VOC emissions**

(Dependent Variable: log10VOC ($R2 = 0.153$))

| Variable | Beta Coefficient | Significance |
|---|---|---|
| Total number of household vehicles | 0.066 | 0.000 |
| Income – 8 groups | 0.033 | 0.000 |
| Office building rentable area | -8.862E-09 | 0.000 |
| Office miscellaneous rentable area | -1.088E-07 | 0.000 |
| Neighborhood retail rentable area | -2.332E-07 | 0.000 |
| Ratio of dwelling units to neighborhood retail attractions | -7.959E-05 | 0.006 |
| Density of streetlights | -2.232E-04 | 0.013 |
| Vacant parcel area | 1.389E-07 | 0.001 |
| Constant | 1.052 | 0.000 |

**Table 54: Regression of household demographics, land use and urban form (quarter mile buffer level) against person-level $NO_x$ emissions**

(Dependent Variable: log10$NO_x$ ($R2 = 0.125$))

The first model explained 15.3% of variation in VOC emissions; the second model accounted for 12.5 percent of $NO_x$ emissions. In both models, variables entered with the expected signs. However, note that in both cases, while all variables are highly significant, the land use variables show only a very minor influence on person level emissions. The models show that as the number of vehicles and household income go up, person level trip emissions also go up. This is consistent with the expectation that individuals with access to personal vehicles will use them to travel to work, and that those with higher incomes tend to drive more. In terms of land use variables, an increase in office or retail space decreased emissions, suggesting that employment areas with more office space and store area will both enable more efficient transit service (and therefore more use), and also will encourage higher rates of walking trip rates to access shops and services. Vacant parcels were positively correlated with emissions, possibly because individuals feel less safe walking or taking transit in these areas, and are therefore more inclined to drive to work if there are numerous vacant parcels in their employment buffer. Interestingly, the density of streetlights entered with moderate significance in the $NO_x$ model, and its negative influence on emissions is stronger than the other land use variables, relatively speaking. In employment locations which are better lit, personal emissions go down. As with vacant parcels, this measure suggests a connection between individual perceptions of safety and the willingness to walk, bicycle, or use transit.

### b) Household Location Analysis

Table 55 and Table 56 show regression results for VOC and $NO_X$ emissions at the household end. With the exception of vacant parcel area, land uses were entered into the household regression models using the number of attractions measure.

| Variable | Beta Coefficient | Significance |
|---|---|---|
| Total number of household vehicles | 0.0510 | 0.000 |
| #Single family units | -0.0003 | 0.000 |
| #Multifamily units | -0.0001 | 0.000 |
| #Educational attractions | -0.0267 | 0.000 |
| #Museums | 0.0849 | 0.006 |
| #Office parks | 0.2040 | 0.000 |
| #Office miscellaneous | -0.0228 | 0.000 |
| #Parks | -0.0444 | 0.004 |
| #Large retail attractions | -0.0631 | 0.000 |
| #Neighborhood retail attractions | -0.0092 | 0.000 |
| Vacant parcel area | -1.146E-06 | 0.006 |
| Constant | 1.3810 | 0.000 |

**Table 55: Regression of household demographics, land use and urban form (quarter mile buffer level) against VOC emissions Dependent Variable: $\log_{10}$VOC (R2 = 0.146)**

The first model explains 14.6% of the total variation in person-level VOC emissions; the second explains 12.8% of the total variance in person-level $NO_x$ emissions. For both models, variables entered with the expected signs, with a few exceptions. Interestingly, income did not enter significantly into either household location model. As with the employment model, as household access to vehicles increases, emissions also increase. Relatively speaking, land uses show a stronger influence on personal level trip emissions in the household models as compared to the employment location models.

| Variable | Beta Coefficient | Significance |
|---|---|---|
| Total number of household vehicles | 0.0423 | 0.000 |
| #Single family units | -0.0003 | 0.000 |
| #Multifamily units | -8.766E-05 | 0.000 |
| #Educational attractions | -0.0231 | 0.000 |
| #Museums | 0.0862 | 0.004 |
| #Office parks | 0.2050 | 0.000 |
| #Office miscellaneous | -0.0170 | 0.003 |
| #Parks | -0.0430 | 0.004 |
| #Large retail attractions | -0.0671 | 0.000 |
| #Neighborhood retail attractions | -0.0070 | 0.000 |
| Vacant parcel area | -1.387E-06 | 0.001 |
| Constant | 1.686 | 0.000 |

**Table 56: Regression of household demographics, land use and urban form against $NO_x$ emissions**
**Dependent Variable: $\log_{10}NO_x$ (R2 = 0.128)**

For both models, increases in the number of educational facilities, parks and large retail attractions resulted in the greatest reduction in personal emissions. Increases in vacant parcel area also resulted in small reductions in personal level emissions, which is the opposite of their influence in the employment location model.

Finally, an increase in the number of museums and office parks in the household buffer were shown to increase personal level emissions. In the case of office parks, the effect is the strongest of any land use measure in either the employment or household location models. This effect is not surprising, given that office parks are usually auto-oriented developments, with large parking lots and non-linear internal street networks. Even if the resident did not work in the office park near their home, they would likely find its presence a disincentive to walking. The relationship between increased numbers of museums and increased personal level emissions is not so clear.

## C. Relationships between GHG Emissions, Land Use and Urban Form

### 1. Modeling Trip related GHG Emissions in EMME/2 and Mobile 6.2

All trips reported by King County households in the Puget Sound Household Activity Survey were modeled at the trip component level. Following this, emissions factors for $CO_2$, $CH_4$, and $N_2O$ were applied, and emissions data were aggregated at the trip and household level. A summary of household level emissions is provided in Table 57.

| | N | Min (g) | Max (g) | Mean (g) | S.D. (g) |
|---|---|---|---|---|---|
| # household trips | 3033 | 1.00 | 126.00 | 18.33 | 13.65 |
| Household $CO_2$ | 2918 | .00 | 99832.21 | 35787.49 | 24404.65 |
| Household $CH_4$ | 2984 | .08 | 920.37 | 138.17 | 103.31 |
| Household $N_2O$ | 2984 | 1.23 | 14917.31 | 2239.44 | 1674.42 |

**Table 57: Summary of household two-day, trip-related GHG emissions, in grams**

$CO_2$ was the single most important household GHG emission, and emissions of all three gases varied considerably between households.

### a) Identifying Correlations between Household GHG Emissions and Urban Form

Once household level data on trip related GHG emissions were assembled, analyses were conducted to identify relationships between these emissions and land use and urban form characteristics at the household location, while controlling for key household demographics. Household size and income are shown above to be primary predictors of vehicle miles of travel, and by extension, of GHG emissions as well. Table 58 shows the steady increase in King County household $CO_2$ production with increases in household size, although efficiency is gained on a per capita basis as tenancy increases above one person per domicile.

| Household size | N | Mean Emissions (g) | S.D. |
|---|---|---|---|
| 1 | 826 | 19567.74 | 16135.21 |
| 2 | 1086 | 35154.81 | 21774.64 |
| 3 | 465 | 46690.14 | 24577.04 |
| 4 | 388 | 50982.11 | 23405.99 |
| 5 | 118 | 55657.81 | 23842.00 |
| 6 | 25 | 55231.23 | 27341.04 |
| 7 | 7 | 56689.12 | 21376.43 |
| 8 | 1 | 74343.07 | -- |
| 10 | 2 | 87633.64 | 8780.51 |
| **Total/Average** | **2918** | **35787.49** | **24404.65** |

**Table 58: Mean Emissions of CO2 by Household Size**

The research team ran preliminary correlations between household GHG emissions and several land use and urban form variables at the household trip end to identify which variables had the strongest relationship with emissions while controlling for household size and income. Based on the results of earlier analyses, the team hypothesized that net residential density, intersection density, and the number of neighborhood retail attractions would show the strongest correlations with household emissions. Log value translations of the dependent emissions variables were used to better distribute their values for analysis. Table 59 shows the results of this correlation analysis.

| | Net Residential Density | Intersection Density | # of Neighborhood Retail Attractions |
|---|---|---|---|
| Log $CO_2$ | -.1948 (.000) | -.1644 (.000) | -.2392 (.000) |
| Log $N_2O$ | -.1987 (.000) | -.1688 (.000) | -.2430 (.000) |
| Log $CH_4$ | -.1988 (.000) | -.1688 (.000) | -.2430 (.000) |

**Table 59: Correlations between Log Emission Values & Urban Form Measures, Controlling for Household Size and Income**

All three variables tested show significant and moderate to strong negative correlations with household trip related GHG emissions, with the strongest correlation between the land use variables and emissions. These results suggest a clear linkage between urban form and land use near the household and emissions:

***Box 4: Interpreting ANOVA Results***

ANOVA, or ANalysis Of VAriance between groups, is a statistical method used to determine if there is any meaning to differences found between groups of data. ANOVA compares variation around the mean values of groups of measurements – for example, household VMT at different levels of intersection density near households – to determine whether differences in that variation would be expected through random chance, of if they indicate that there are meaningful differences between the groups themselves, and therefore a relationship between variation in the data and the measure used to define the groups – in this case, intersection density.

An F statistic near or below one indicates that differences between groups are not meaningful; higher F statistic values indicate stronger differences between groups. Significance (or P value) indicates how likely the finding of a relationship is due to random chance. P values of 0.05 or less can be considered significant.

In the analyses presented here, the difference in at least one pair of mean values for each VMT is statistically significant.

as residential density, the connectivity of the street network, and the number of neighborhood retail attractions increases, household emissions go down. Based on the earlier correlation analyses, a likely explanation for this outcome is increased rates of walking in neighborhoods with these characteristics, especially large numbers of unique retail attractions. As has been the case thus far, mixed use, as measured by the presence of neighborhood retail attractions, was the best independent predictor.

A second correlation analysis was conducted which controlled for VMT in order to isolate the effect of net residential density alone on $CO_2$ production. This analysis resulted in a Pearson r for net residential density of -.1709 at the .000001 level of significance. This finding suggests that average travel speed associated with increased levels of density and connectivity may precipitate lower emissions levels per unit of distance travelled.

### b) GHG Regression analysis

After identifying individual correlations between household demographics, VMT, urban form, land use and emissions, the research team then developed a multivariate linear regression model to further investigate the relationship between all of the significant independent variables and one of the dependent emissions variables, the log value of household trip related $CO_2$ emissions. The regression model was developed in five stages, starting with household demographics alone in model one, then adding in VMT, and finally including all the urban form and land use variables in model five. Results of the regressions are shown in Table 60 below.

### c) Household CO2 and Urban Form at the Place of Residence

# CO2 Emissions and Urban Form at the Place of Residence

**Model Summary**

| | | | Adjusted | Std. Error of |
|---|---|---|---|---|
| 1 | .461 [a] | .212 | .212 | 1.00040 |
| 2 | .639 [b] | .409 | .408 | .86693 |
| 3 | .660 [c] | .435 | .434 | .84739 |
| 4 | .663 [d] | .440 | .439 | .84390 |
| 5 | .665 [e] | .443 | .442 | .84192 |

a. Predictors: (Constant), income greater / less than

b. Predictors: (Constant), income greater / less than

c. Predictors: (Constant), income greater / less than $35K, household size, vmt - all vehicles, #

d. Predictors: (Constant), income greater / less than $35K, household size, vmt - all vehicles, #

e. Predictors: (Constant), income greater / less than $35K, household size, vmt - all vehicles, # neighborhood retail, zscore intersection density, net

**Coefficients [a]**

| | | Unstandardized | | Standardized Coefficien | | |
|---|---|---|---|---|---|---|
| 1 | (Constant) | 8.293 | .086 | | 95.941 | .000 |
| | household size | .305 | .017 | .333 | 18.237 | .000 |
| | income greater / less than $35K | .633 | .049 | .235 | 12.894 | .000 |
| 2 | (Constant) | 8.409 | .075 | | 112.101 | .000 |
| | household size | .129 | .016 | .140 | 8.198 | .000 |
| | income greater / less than $35K | .458 | .043 | .170 | 10.662 | .000 |
| | vmt - all vehicles | 049E-03 | .000 | .495 | 29.358 | .000 |
| 3 | (Constant) | 8.626 | .076 | | 113.636 | .000 |
| | household size | .114 | .015 | .125 | 7.436 | .000 |
| | income greater / less than $35K | .412 | .042 | .153 | 9.761 | .000 |
| | vmt - all vehicles | 752E-03 | .000 | .474 | 28.585 | .000 |
| | # neighborhood retail | 3.57E-02 | .003 | -.168 | -11.050 | .000 |
| 4 | (Constant) | 8.613 | .076 | | 113.856 | .000 |
| | household size | .110 | .015 | .120 | 7.197 | .000 |
| | income greater / less than $35K | .423 | .042 | .157 | 10.050 | .000 |
| | vmt - all vehicles | 707E-03 | .000 | .471 | 28.487 | .000 |
| | # neighborhood retail | 3.11E-02 | .003 | -.146 | -9.234 | .000 |
| | zscore intersection density | 3.36E-02 | .018 | -.073 | -4.740 | .000 |
| 5 | (Constant) | 8.718 | .081 | | 107.855 | .000 |
| | household size | .102 | .015 | .111 | 6.559 | .000 |
| | income greater / less than $35K | .410 | .042 | .152 | 9.728 | .000 |
| | vmt - all vehicles | 671E-03 | .000 | .468 | 28.375 | .000 |
| | # neighborhood retail | 2.58E-02 | .004 | -.121 | -7.072 | .000 |
| | zscore intersection density | 7.12E-02 | .018 | -.063 | -3.970 | .000 |
| | net residential density | 6.03E-03 | .002 | -.064 | -3.634 | .000 |

a.

**Table 60: Household CO2 Emissions and Urban Form at the Home Trip End**

Table 60 shows that model one, containing only household demographic variables, explains approximately 21 percent of the variation in $CO_2$ production, as represented by the R Square value in the model summary table. In model two, adding VMT increased the explained variation in $CO_2$ to 41 percent. Model 3 incorporates a key land use variable, number of neighborhood retail uses in the household buffer, which increases explained variation by approximately 3 percent. Model 4 brings in intersection density, which adds less than 1 percent to the model's explanatory power. Finally, model 5 adds in net residential density, which increases explanatory power by less than 1 percent. Under model five, the total explained variation in household trip related $CO_2$ emissions is 44.2 percent. It is important to note that while the land use measures were significant after VMT was entered into the model, the explained variation was only modest from each variable. This makes sense since the primary contribution of land use is in its ability to explain VMT – as demonstrated in previous analyses in this chapter. Again, it is assumed that the remaining variance explained by land use after VMT is entered into the model is a function of a more favourable average speed profile for households within more urban environments, in terms of $CO_2$ production. This relationship needs further investigation given the nature of more urban conditions where per unit of distance of travel is often assumed to be associated with increased energy consumption – and by default, more $CO_2$ production.

As the standardized beta coefficients in the five models show, changes in household VMT will clearly have the greatest influence on household trip related $CO_2$ emissions. As with household size and income, when household VMT goes up so do household trip related $CO_2$ emissions. This finding is to be expected. However it is important to note that while adding land use and urban form variables to the model increased the overall proportion of explained variation in emissions by less than 5 percent, the influence of these land use and urban form variables on household emissions can be interpreted as being relatively significant, as shown by their standardized coefficients and T statistics. In fact, as the final model shows, the variation in the number of neighborhood retail uses within a quarter mile of the household has approximately the same absolute influence on household emissions as household size and income. Net residential density and intersection density were far less significant. Neighborhood residential density is not a strong predictor of household travel behavior (and hence household emissions) by itself. It is what happens in those neighborhoods -- the variation in land uses available – that influences household travel. A great deal of the variation in household VMT is explained by the urban form variables found in this model. Further investigation is required in these relationships.

### d) Person Level $CO_2$ and Urban Form at the Place of Employment

The following sequence of models presented in Table 61 documents significant relationships between $CO_2$, per capita VMT, and urban form measured at the place of employment.

## Person Level

# CO2 Emissions and Urban Form at the Place of Employment

**Model Summary**

| | | | Adjusted | Std. Error of |
|---|---|---|---|---|
| 1 | .076 [a] | .006 | .005 | 1.07185 |
| 2 | .526 [b] | .277 | .277 | .91405 |
| 3 | .546 [c] | .298 | .297 | .90080 |
| 4 | .553 [d] | .306 | .305 | .89586 |
| 5 | .558 [e] | .311 | .310 | .89254 |
| 6 | .559 [f] | .313 | .311 | .89181 |

a. Predictors: (Constant), household size, household

b. Predictors: (Constant), household size, household

c. Predictors: (Constant), household size, household

d. Predictors: (Constant), household size, household income, person vmt, OMBLDGS, net residential density

e. Predictors: (Constant), household size, household income, person vmt, OMBLDGS, net residential density

f. Predictors: (Constant), household size, household income, person vmt, OMBLDGS, net residential density

**Coefficients [a]**

| | | Unstandardized | | Standardized Coefficien | | |
|---|---|---|---|---|---|---|
| 1 | (Constant) | 9.547 | .049 | | 194.360 | .000 |
| | household income | 691E-03 | .001 | .032 | 1.835 | .067 |
| | household size | 792E-02 | .014 | .070 | 4.006 | .000 |
| 2 | (Constant) | 8.903 | .046 | | 194.565 | .000 |
| | household income | 975E-03 | .001 | .037 | 2.512 | .012 |
| | household size | 410E-02 | .012 | .041 | 2.761 | .006 |
| | person vmt | 165E-02 | .000 | .522 | 34.966 | .000 |
| 3 | (Constant) | 8.963 | .045 | | 196.990 | .000 |
| | household income | 782E-03 | .001 | .034 | 2.299 | .022 |
| | household size | 734E-02 | .012 | .033 | 2.243 | .025 |
| | person vmt | 164E-02 | .000 | .522 | 35.466 | .000 |
| | OMBLDGS | 2.03E-02 | .002 | -.145 | -9.873 | .000 |
| 4 | (Constant) | 9.034 | .047 | | 193.286 | .000 |
| | household income | 866E-03 | .001 | .035 | 2.420 | .016 |
| | household size | 222E-02 | .012 | .027 | 1.828 | .068 |
| | person vmt | 153E-02 | .000 | .517 | 35.261 | .000 |
| | OMBLDGS | 2.04E-02 | .002 | -.146 | -9.999 | .000 |
| | net residential density (work) | 1.01E-02 | .002 | -.089 | -6.082 | .000 |
| 5 | (Constant) | 9.027 | .047 | | 193.781 | .000 |
| | household income | 705E-03 | .001 | .032 | 2.218 | .027 |
| | household size | 170E-02 | .012 | .026 | 1.793 | .073 |
| | person vmt | 153E-02 | .000 | .516 | 35.374 | .000 |
| | OMBLDGS | 1.67E-02 | .002 | -.120 | -7.729 | .000 |
| | net residential density (work) | 3.58E-03 | .002 | -.076 | -5.094 | .000 |
| | NB_REST2 | 5.00E-02 | .010 | -.079 | -5.028 | .000 |
| 6 | (Constant) | 9.011 | .047 | | 191.720 | .000 |
| | household income | 746E-03 | .001 | .033 | 2.273 | .023 |
| | household size | 104E-02 | .012 | .025 | 1.739 | .082 |
| | person vmt | 157E-02 | .000 | .518 | 35.487 | .000 |
| | OMBLDGS | 1.60E-02 | .002 | -.115 | -7.348 | .000 |
| | net residential density (work) | 3.39E-03 | .002 | -.074 | -4.979 | .000 |
| | NB_REST2 | 5.44E-02 | .010 | -.086 | -5.388 | .000 |
| | # fast food restaurants work | 293E-02 | .021 | .037 | 2.505 | .012 |

a.

**Table 61: Person Level CO2 Emissions & Urban Form at the Employment Trip End**

As with the household level assessment, VMT (t=35.48 in the final model) was the most significant predictor of $CO_2$. Once again, the addition of urban form variables raised the amount of explained variation as well. However the influence of these variables was slight: the number of commercial buildings was inversely associated with $CO_2$ emissions and raised explained variation by approximately 2 percent, net residential density was also inversely associated and raised explained variation by less than 1 percent, neighborhood restaurants were inversely associated and increased explained variation by approximately 1 percent, and the number of fast food establishments was positively associated and raised explained variation by $1/10^{th}$ of one percent. It is interesting to note that restaurants are significantly associated with a reduction in $CO_2$ emissions whereas fast food establishments were associated with an increase in $CO_2$ emissions. This result reinforces the contrasting the urban context in which these different types of eateries tend to be located: fast food establishments tend to be located in more auto oriented areas, and restaurants are perhaps somewhat more prolific in older established urban villages.

## D. Summary of GHG and CAC emissions analysis

The findings presented here document important relationships between land use, urban form and trip level emissions within King County. In particular, they reinforce earlier findings that land uses where we live and work influence our travel behavior, in particular levels of vehicle travel. They also draw a clear connection between land uses and personal level travel related emissions. We found that increases in residential density, land use mix, and street connectivity at household and employment locations are associated with reductions in per capita levels of $NO_x$, VOCs, and CO when controlling for household income and size. Interestingly, emissions are more sensitive to increases at the household end for all these urban form and land use variables. At the employment location, emissions were most sensitive to increases in office and retail space. Generally speaking, other results suggest that changes in land use variables which improve transit service efficiency, make walking to secondary destinations feasible, and improve the perception of safety of the local environment all tend to decrease emissions as well. In the case of GHG emissions, results show that emissions are sensitive to increases in net residential density, street connectivity and the number of retail uses near the home, when controlling for household size and VMT. Land uses were shown to have a larger influence on emissions than residential density itself. The $CO_2$ results presented are among the first results to date that clearly link climate change with travel patterns, and urban form at both the place of residence and place of employment. Urban form variables apparently impact $CO_2$ indirectly through VMT and directly through travel speed and engine modal operation, or through cold start functions.

These findings generally support the conclusions reached in the walking, transit and VMT/VHT analyses presented earlier. They show that strategies aimed at changing land use patterns and urban form in order to encourage use of alternatives to the private automobile will also have a significant influence on regional travel emissions. This information will provide guidance as King County and the Puget Sound Region Council move towards policies and plans to improve regional air quality.

## E. Physical Activity: Analysis of Relationships

Self-reported physical activity from the Silver Sneakers data set was found to be positively associated with several measures of land use and urban form. Correlation results are presented in Table 62 below. N represents the number of respondents for which data was available for the measurement of the strength of each association.

| | |
|---|---|
| Frequency of weekly exercise and area of recreational open space (N=295) | .178 (.002) |
| Number of leisurely walks and street network connectivity (N = 579) | .126 (.002) |
| Number of leisurely walks and number of entertainment uses (N=341) | .120 (.027) |
| Number of leisurely walks and number of retail uses (N = 353) | .103 (.052) |
| Number of leisurely walks and residential density (N = 112) | .222 (0.08) |

**Table 62: Correlations between physical activity, land use and urban form**

The strongest correlation identified was that between reported frequency of weekly exercise and area of nearby open space, suggesting that neighborhood parks may be an important resource for elderly residents wishing to engage in physical activity. Interestingly, the land use measure of significance is the area, not the number of parks. This runs counter to the finding reported in the previous walking analysis, which found that the number of parks is a more important correlate with walking rates than the size of parks. It may be the case that for the purposes of engaging in exercise, the size of parks *is* important; for example, small parks may not provide enough area to allow people to engage in effective brisk walking, or enough of a sense of privacy to allow participants to feel comfortable engaging in more formal exercise activities such as Tai-Chi.

The frequency with which respondents partake of leisurely walks also showed significant correlation with a number of urban form and land use measures, though none showed as strong an association as that between exercise and open space. The relationship between street connectivity and leisurely walking may reflect the range of walking options provided by gridiron versus cul-de-sac street networks.

In a gridiron street network with short block lengths, walkers have numerous opportunities to vary their route, to investigate interesting activities or features glimpsed up side streets, and to shorten or lengthen their walk without retracing their steps along the same roads. In contrast, in hierarchical street networks with curvilinear streets and cul-de-sacs, walkers have fewer route options, opportunities to change direction are some distance apart (and often out of sight around curves), and varying the length of a walk often means simply turning around and walking back along the same route.

The number of leisurely walks taken by participants was also correlated with the number or entertainment and retail land uses. This may be related to the visual interest such uses bring to the streetscape, as well as the opportunity they provide for impromptu stops or completion of errands. Correlation between the number of walks and the number of retail uses in the buffer was significant only at the 90 percent level.

Finally, though not statistically significant, a strong correlation was identified between walking trip rates and residential density when controlling for household income. As discussed in the walking trip analysis, this correlation likely reflects the greater mixing of land uses found in high density areas, as well as the increased variation in streetscapes, built forms and activity found in such neighborhoods. For many people, denser neighborhoods are more interesting to walk through. Even though individuals partaking of leisurely walks may not have specific destinations in mind, they may be more likely to take those walks if the walking environment presents a stimulating variety of land uses and potential destinations.

## VI. Summary of Regional Findings and their Application to Case Studies

The research described here has resulted in some significant findings about the relationship between land use, urban form, travel behavior and trip level emissions. Among the highlights:

### A. Land Use, Urban Form and Walking

- The land uses most strongly correlated with the percentage of household walk trips proved to be educational facilities, commercial office buildings, restaurants and taverns, and neighborhood-scale retail establishments. These findings are to be expected. It is intuitive that having these establishments within a quarter-mile of a residence allows individuals to accomplish major trip purposes, such as work trips and shopping trips, by walking. Of the 17 land uses measured, only high-tech industrial uses and office parks failed to have statistically significant correlations for any of the three measurement categories.
- The mix of land uses in a neighborhood was found to have a greater influence on the decision to walk than the number of destinations of a particular type of use, or the total area of a particular use.
- Steep increases in parking costs near the home were shown to have a small effect on personal walking trip rates.

### B. Land Use, Urban Form and Transit Usage

- In terms of transit usage, the statistical analysis supports an ideal land use scenario of a limited number of household supporting land uses on the household trip end, and a large number of work, shopping, and entertainment attractions on the employment end.
- The degree of land use mix and the number or restaurants and taverns near the household were both positively associated with transit use for the trip to work.

- Unsurprisingly, the land uses best associated with the percentage of work trips by transit are also those associated with typical downtown areas: commercial office floor space; retail floor space; the number of large retail attractions, which typically function as "anchor" stores in retail development projects; entertainment uses, such as movie theaters and sports attractions; and restaurants and taverns all show strong positive associations with transit use.

- Net residential density and employment density near the workplace were also positively associated with increased transit usage for the trip to work, as were the number of bus stops near the work place.

- Vacant parcel area was negatively correlated with transit use at a statistically significant level. Since the parcels lack a meaningful destination attraction, their presence should discourage people from using transit to access a given location. The larger the vacant area, the less the attractiveness of the destination. In addition, perceptions of safety in environments with large numbers of vacant lots may also lead travelers to choose private vehicles over transit when traveling to or through such areas.

## C. Land Use, Urban Form and VMT/VHT

- Increases in several land use variables resulted in decreases in household VMT. An increase in the number of grocery stores, educational facilities, parks and convenience stores all accounted for weak, but significant, decreases in VMT. Given that these trip purposes account for only a small share of the number of trips generated by a household and that these trips typically tend to be shorter than work trips, dramatic reductions in VMT resulting form the presence of these uses would have been unlikely. Still, their presence does account for statistically significant reductions in VMT – reductions which may be important in areas with concerns about diminishing air quality and congestion.

- Since public school children are typically assigned to the school closest to their home, the presence of nearby educational facilities appears to reduce household VMT by reducing the distance parents need to travel to drop off or pick up their child. Further, because these facilities are within a quarter-mile of the survey households, it is equally as likely that the drive trips are replaced entirely by walk trips – in other words, rather than needing to be driven to school, children have the ability to walk or bike as well, eliminating an automobile trip completely.

- It was surprising at first that the proximity of grocery stores did not show a stronger relationship with reductions in household VHT, since grocery trips are necessary to sustain a household, and one would have expected the presence of nearby groceries to reduce or eliminate vehicle trips altogether. A closer examination of the characteristics of grocery trips appears to explain the weakness of the measure, however. The frequency of grocery trips tend to be sensitive to distance. Where grocery stores are not conveniently located near one's household, we suspect that individuals needing to travel to these locations make fewer trips, but purchase a greater quantity of items, thereby increasing the period of time before they are required to travel to the grocery again. Conversely, individuals with grocery stores near their homes tend to make more trips, picking up items as they are needed.

- Increasing the number of fast food restaurants within the quarter mile household buffer significantly decreases the amount of VHT generated by a household. This seems to fly in the face of the conventional planning concept of a "livable" neighborhood. Nevertheless, to the extent that lowered household VHT is an important feature of more livable neighborhoods, fast food restaurants may not be entirely undesirable.

## D. Land Use, Urban Form and Trip Level Emissions

- Relationships between land use, urban form and trip level emissions generally confirmed the results found in the walking, transit and VMT/VHT analyses. Emissions were found to be more sensitive to changes in land use at the household location than at the employment location.

- Land uses at the employment end of trips had only a modest influence on $CO_2$ emissions, with the number of commercial buildings, net residential density, and restaurants showing small negative associations with emissions. The number of fast food restaurants near the employment location was positively associated with $CO_2$ emissions.

- While the influence of land use on trip emissions was found to be relatively weak, the effects were still significant, and in communities facing air quality problems emphasis on the long term increase in land use mix in residential areas may help meet goals for air quality attainment. In particular, the research found that increasing the number and variety of retail attractions in a neighborhood had a greater reductive effect on emissions than increasing residential density or street connectivity.

- The relationship between land use, urban form, VMT/VHT and $CO_2$ emissions in dense urban areas is complex and requires further investigation.

## E. Land Use, Urban Form and Physical Activity

- Analysis of the Silver Sneakers data set revealed that walking as a leisure activity is influenced by land use and urban form. Individuals were found to be more likely to walk as a form of leisure activity in neighborhoods with higher street connectivity and a greater number of entertainment and retail uses. These results indicate that walking as an end in itself is more likely to take place in neighborhoods with short blocks, numerous intersections and mixed land uses.

## F. Land Use, Urban Form and Planning For more Sustainable, Less Auto-Dependent Communities

- One of the more interesting findings of this study, from an implementation perspective, is that for some land uses rentable floor area proved to be the best measure with the strongest relationship to household walking trip rates. For other land uses, the number of unique attractions proved the measure with the strongest relationship to walking. Selecting the right unit of measurement when specifying land uses in planning guidance documents will allow practitioners to better measure their progress as they attempt to achieve goals such as encouraging non-motorized travel.

- Appropriate performance measurement is necessary for successful implementation. In developing land use guidelines to encourage walking in project level and comprehensive plans, this study recommends that guidelines for retail and commercial uses be presented in terms of their rentable square feet. Guidelines for parks, groceries, educational facilities, and restaurants would best be presented in terms of the number of unique attractions in the development, planning area or neighborhood.

- The research results also clearly show that the importance of net residential density and street connectivity in determining travel behavior is often over-emphasized. The finding that density plays less of a role than was previously thought is significant, because it moves us beyond the simple guidance that "higher density is better" to a more nuanced appreciation of the influence of density and land use on travel behavior. The results of this research showed that the mix of land uses in a neighborhood consistently had a greater influence on travel behavior than density alone. Likewise, more intersections – greater street connectivity – do not automatically translate into more places to walk to. The results of this research show that intersection density and increased mix of uses play complementary roles in encouraging people to choose alternatives to the car.

## G. Application of the Findings at the Community and Regional Levels

It is important to note that these relationships are likely to vary between communities, making community-specific data a necessity. Although various types of strategies are suggested by the research conducted at the regional level, different subsets of strategies will be applicable at the community level, depending on each community's unique conditions. The following chapter of this report examines the existing conditions in a set of three communities and applies the regional findings in the form of recommended strategies for street network redesign, neighborhood commercial development and compact residential development that can be used to promote walking and transit use, decrease auto dependence, and increase levels of physical activity and overall health. Figure 37 below shows the overall relationship of the regional level research to the community level applications.


**Figure 37: Overall Relationship of the Regional Level research and Community Level Applications**

Some strategies arising from the regional findings, including changes to land use regulations, growth management policies, and transit service reallocation, will not necessarily have community level applications. These strategies will be discussed further in the Chapter 6, the final chapter of this report.

# Chapter V: Case Study Application of the Regional Findings

## I. Overview

This chapter of the report takes the regional level findings and considers their application in the specific context of three King County communities: Kent, Redmond and White Center. The case studies of these communities start with an examination of existing land use and urban form conditions, population demographics, and the travel behavior of community residents. The case studies also present a snapshot of resident perceptions of community walkability and transit accessibility, and their current level of satisfaction with the community characteristics. Next, the case studies present a series of recommendations for community specific urban redevelopment and transportation programming strategies which, based on the regional findings, could be used to increase walking rates and transit ridership and reduce vehicle related emissions at the community level. Finally, the case study analysis ends with a review of resident preferences among possible changes to land use and urban form. In short, the case studies described here identify community level strategies that arise from the regional level research findings, and compare these to existing built environment conditions and aspirations of community residents for change. The focus is on land use and urban form at the household end of trips in whole communities, and not on the application of the regional research findings to individual employment destinations or major employment centers. Respondent use of transportation demand management (TDM) measures for the trip to work are presented in Chapter VI.

## II. Methodology

There were two major components to the case studies: on the ground analyses of existing land uses and urban form and a comprehensive survey of community residents. The survey included questions on travel behavior, attitudes towards walking and taking transit, the relative importance of different neighborhood characteristics on willingness to use those modes, and preferences among a series of possible changes to the neighborhood built environment. Methods used in these two components of the study will be described below after a brief description of the case study selection process.

### A. Criteria used to Select the Case Study Locations

#### 1. Geographic Dispersion

King County requested that one case study be selected from each of the county's three sub-planning areas recognized by PSRC's transportation planning and programming process: the West Side, the East Side, and South County.

## 2. Demographic Variation

The County also wanted to examine transportation problems across a range of "demographic environments," in order to address environmental justice and equity considerations that are increasingly central to transportation and mobility planning.[1]

## 3. Range of Urban Environments

Because a primary purpose of King County's Smart Growth Initiative is to test the viability of various transportation service and investment, land use, and TDM strategies within a wide range of urban form conditions, it was incumbent upon the study team to select case study locations which were as different from one another as possible. Therefore, study sites were selected from an older urban center, an auto oriented suburban district, and a suburban town center.

## 4. Jurisdictions of Influence

The research team also recognized that it was important to maximize the likelihood that the results from the study will be implemented. Therefore, it attempted to locate study areas where jurisdictional overlap was minimal in order to increase flexibility in implementing recommendations. The team also sought out areas that were previously targeted for transportation and land use improvements in order to build upon existing momentum for change.

## 5. Demonstration Opportunities

The study team also sought areas that would demonstrate the potential of various strategies to reduce auto dependence and improve the overall quality of life in communities across the county. Each case study was selected based on either its potential for retrofit and change, or the transferability of its particular attributes to other locations of the county.

Based on data collection, site visits, and consultation with King County staff, case study locations selected were Kent East Hill, to the north of Downtown Redmond, and in White Center. Each of the case study locations chosen is also included as a case study location in the Neighborhood Quality of Life Study (NQLS), a broader study sponsored by the National Institutes of Health (NIH), and directed by

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1 Requirements for equal representation of ethnic and income groups in transportation investments have been written into federal transportation regulations and extend out of Title VI of the Civil Rights Act and recent Presidential Executive Orders. Equity considerations are fundamental to the estimation of "benefits" and "burdens" of transportation investment programs countywide and have been the foundation of legal challenges within the County and other parts of the nation.

Dr. James Sallis of San Diego State University.

The NIH study also characterized case study areas according to an income-walkability matrix, with walkability represented by a composite measure derived from intersection density, retail floor area ratio, net residential density, and land use mix within the census block groups representing the study areas. According to the matrix, Kent East Hill is considered a "low-walkability, low-income" community, Redmond is considered a "low-walkability, high income" community, and White Center is considered a "high-walkability, low-income" community.[2]

Figure 38 shows the general location of the three case study locations, as well as the remaining case studies included in the NQLS.

## B. Review of Case Study Performance According to the Study Criteria

### 1. Geographic Dispersion

The case studies represent each of the sub-planning areas: White Center is located in the West Side, Redmond on the East Side, and Kent East Hill in the South County area, as shown in Figure 38.

2 The NIH study also includes "high-walkability, high-income" communities, such as the Queen Anne and Capitol Hill districts in Seattle. However, King County indicated that the goals of the study described here would be better served by analyzing the three community types described above.

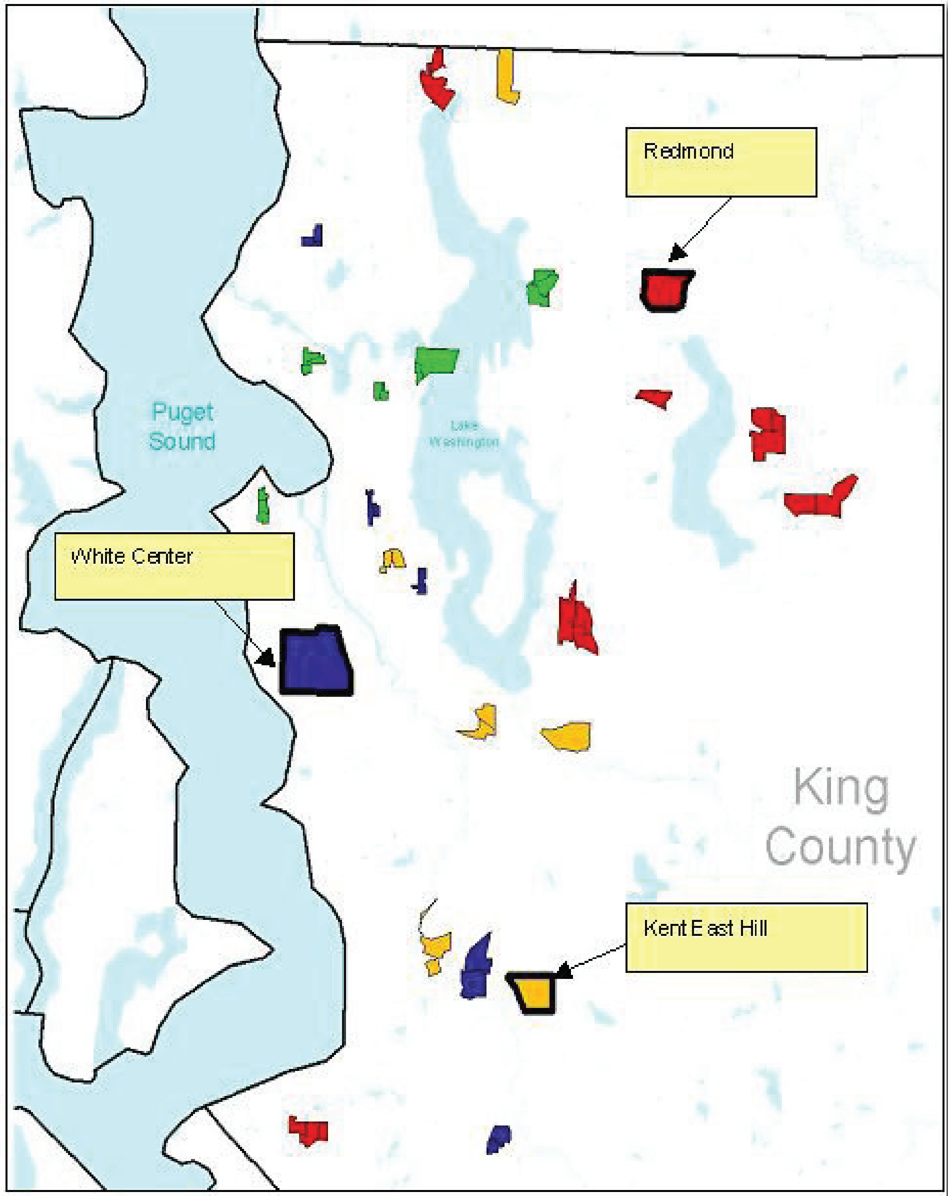



**Figure 38: Location of Case Study sites in King County**

## 2. Demographic Variation

White Center is lower income and mostly non-White, Redmond is upper income and primarily White, and Kent East Hill is ethnically mixed and lower to middle income.

## 3. Range of Environments

White Center is an older urban center with a connected street network, some mixing of uses, and poor pedestrian infrastructure; Redmond is a low density residential suburban area with few pedestrian amenities and little nearby commercial development; and Kent East Hill is an auto-oriented suburban area with a considerable amount of high density residential development located in close proximity to shopping.

### 4. Jurisdictions of Influence

White Center is located primarily in unincorporated King County and currently has underway a major planning effort sponsored by funding from the Annie E. Casey Foundation. The area is changing fast and is likely to undergo redevelopment. Redmond is a rapidly growing incorporated city which has recently updated its comprehensive plan and developed a new transportation plan for the downtown core with the aim of improving community quality of life. Kent East Hill is recognized by the PSRC as a "Secondary Activity Center." Activity nodes are "locations [which] may have concentrations of higher-density residential development, some mix of land uses (such as shopping or offices in addition to housing), and the potential to develop a nonmotorized network that makes it easier to walk, bike or use transit." (PSRC 2005).

### 5. Demonstration Opportunities

White Center presents several demonstration opportunities. These include improvements to pedestrian infrastructure within the context of a well connected, grid street network; development of complementary commercial uses, increased residential densities and a greater variation of housing prices and products; and improvements to transit service.

Redmond is an environment that "works," and the city provides some good examples of on-the-ground best practices. However, demonstration projects could include improved transit service to regional centers, focused recruitment of specific retail uses within residential areas, and targeted pedestrian improvements between neighboring residential areas and the central commercial core.

Kent East Hill represents a typical example of late 20$^{th}$ century suburban development: it has a good mix of land uses and high density multifamily housing, but poor site design and low street connectivity which reduce accessibility, and a deficit of park and open space resources. In order to become more walkable and transit friendly neighborhoods, communities such as Kent will require significant retrofits of their street network, the establishment of a pedestrian realm, and significant site design changes to the commercial core. Kent East Hill offers the ability to demonstrate transportation, air quality, and physical activity benefits associated with a major suburban retrofit, and its results will be relevant to numerous similar communities in the county.

## C. Methods used to Analyze Case Study Land Use and Urban Form Data

The analysis of current built environment conditions in the case study areas relied on detailed parcel level land use data developed and collected by King County and the Puget Sound Regional Council, in conjunction with data obtained from numerous site visits by the Case Study team. Whereas analysis of regional land use and urban form data was based on household and employment buffer areas, case study data was aggregated at the level of the census units which comprise the case study location.[3] Each case study site was examined in isolation and in comparison; with particular attention given to urban form elements and land use variables that were thought to have significant influence on travel behavior, and hence air quality and public health.

Recommendations were developed both to address the specific deficiencies in urban form, transportation infrastructure and land use policies identified in each community, as well as to take advantage of the positive features present in each community. Recommendations have been inspired by three sources: a brief survey of best practices of other West Coast municipal and regional agencies which are working to create more 'livable' and sustainable regions; past urban design research done for the State of Washington and regional agencies; and finally, ideas and strategies for transit oriented developments and walkable neighborhoods developed by leading West Coast urban design thinkers.

## 1. Methods used in Case Study Travel Behavior, Attitude and Preference Surveys

### a) Sample Selection and Recruitment Methods

Households were selected from two sources: 1) a listing of prior participants in NQLS who live in households in one of the three communities and 2) randomly selected community households from marketing company household lists. Up to four individuals within each household were eligible to participate.

Census block groups that were equivalent to the community areas were compared with the NQLS database to generate a list of eligible households from that study. All eligible NQLS households were sent an introductory letter asking for participation in the study. In order to recruit non-NQLS households, community census block groups were provided to a marketing company which randomly selected households with and without telephone numbers who lived in the identified block groups. All randomly selected households were also sent the introductory letter.

Two or three days after expected letter delivery, telephone contact was attempted with all households for which telephone numbers were available. Telephone recruiters explained the study, and determined household eligibility and interest in participating. Initially, it was necessary that all individuals in the household agree to participate in order for the household to be eligible to participate. Households agreeing to participate were then sent a consent form to review and sign, with a business reply envelope in which to mail back the signed consent form. After receiving the consent form, households were mailed the appropriate number of travel surveys and diaries to complete, with a postage paid return

3 Each case study area is actually comprised of two or three separate block groups—a unit of Census geography that contains 600 to 3,000 people. Source: Census 2000 Geographic Terms and Concepts, page A-8.

envelope to mail back the materials.

An introduction letter and business reply return post-card were mailed to households for which telephone numbers were not available. Households interested in participating were encouraged to mail back the post-card with contact information provided (e.g., telephone number). After receiving the post-card, telephone recruiters contacted the household to introduce and explain the study. Survey recruitment and collection of completed surveys took place between April and November 2003.

As an incentive for participation, households were eligible to receive $15 for each participant 16 years or older and $10 for each participant between the ages of 6-15. This incentive was similar to that provided in previous studies using similar methodologies. Only households which provided complete data for all eligible household members received any payment.

Individuals not residing in group-living establishments (e.g., nursing homes, dormitories, or military barracks), living in households in which there are fewer than five members 6-65 years old, who are able to travel outside the home, able to complete written surveys in English, and are between 6-65 years old were eligible to participate in the study.

### b) Survey Instruments used in the Study

#### (1) Household Questionnaire

The household survey consisted of items specific to the household rather than any individual in the household, including questions about dwelling type, length of time at current residence, automobile ownership, accessibility of destinations, community satisfaction, ranking of potential public investments and preferences among different community archetypes. The household survey was completed by one adult over 18 years old in the household. Two versions of this survey were developed, one for NQLS participants and one for non-participants. The survey for NQLS participants did not include questions on demographics previously collected from these individuals. A copy of the Household Questionnaire for a non-NQLS household is provided in Appendix I. A total of 461 households provided completed household surveys. Average household sizes were 2.3 in White Center, 2.4 in Kent East Hill and 2.5 in Redmond.

#### (2) Individual Questionnaire

The person-level travel survey consisted of questions related to individual demographics such as age, income and employment, travel to work, familiarity with TDM programs, and community walkability, and was completed by household members 16 or older. A total of 600 individuals provided completed individual surveys. A copy of the Individual Questionnaire is provided in Appendix II.

### (3) Community Travel Diary

The travel diary, which participants completed daily for two days, is considered an activity-based diary. Activity-based travel diaries assess location, activity engaged in, and time spent at each location (e.g., home, work, and store) throughout the day, rather than asking only about travel from place to place. Activity-based travel diaries tend to more reliably capture short (e.g., walking trips) and linked trips (e.g., going to the grocery store on the way home from work) than tools relying solely on report of travel modes and time spent traveling. Two diaries were developed: a standard version for adults, and a simplified version for children. Household members 16 or older completed their own travel diaries and an adult household member over 18 years old completed the travel diaries for household members who are 6-15 years old. Each travel diary sent out requested completion over a specific two day period (i.e. Monday-Tuesday, Thursday-Friday) to ensure sampling variation and an even distribution of collected travel data. A total of 908 correctly completed travel diaries were collected for individuals from the three communities. A copy of the Community Travel Diary is provided in Appendix III.

Recruitment rates were highest in Redmond and lowest in Kent East Hill. Sampling boundaries for Redmond were expanded to better overlap with the NQLS study area for that community. In addition, after exhausting other options for increasing response rate in Kent, the sampling boundaries for that community were expanded considerably to enable recruitment of a sufficient numbers of respondents for data analysis. To further enhance recruitment, in the fall of 2003 the requirement that all individuals in a household must agree to participate in the survey was dropped. Additional discussion of recruitment methods, changes to study area boundaries, and data collection and analysis issues can be found in Appendix IV.

### (4) Response Rates

Overall survey response rates break down as shown in Table 63. Taking the recruitment rate to be the number recruited divided by the sum of recruitments and refusals, the survey had a recruitment rate of 37 percent.[4] Of the 845 recruited, 469 households completed surveys for a household response rate of 20 percent. Recruitment and response rates by community are presented in Table 64 below.

4 This method of calculating response rates was used in other sections of the NQLS study.

| Category | Sample Outcome | Frequency | Percent |
|---|---|---|---|
| **Eligible sample** | | | |
| | Recruited | 845 | 13% |
| | Refused | 1470 | 23% |
| | Unable to contact | 4123 | 64% |
| **Sub-total eligible** | | **6438** | **100%** |
| **Ineligible sample** | | | |
| | Letters undelivered | 648 | 21% |
| | Stopped recruitment | 838 | 27% |
| | Did not meet criteria | 837 | 26% |
| | Phone disconnect etc. | 805 | 25% |
| | Other (deceased etc.) | 31 | 1% |
| **Sub-total ineligible** | | **3159** | **100%** |
| **Total sample** | | **9597** | |

**Table 63: Overall Survey Response Rates**

| | Recruitment | | Final response rate | |
|---|---|---|---|---|
| | **Frequency** | **Percent** | **Frequency** | **Percent** |
| **Kent** | 318 | 32% | 157 | 16% |
| **Redmond** | 213 | 42% | 134 | 26% |
| **White Center** | 314 | 38% | 178 | 22% |
| **Total** | 845 | 37% | 469 | 20% |

**Table 64: Community Level Recruitment and Response Rates**

Sample errors at the 95 percent confidence interval for household and individual data collected through the three surveys are shown in Table 65 below. Results assume no bias in the sampling procedure.

| Household Survey | Sample Size | Margin of Error |
|---|---|---|
| | | |
| **All households** | 461 | ± 5.00 percent |
| **Kent East Hill** | 155 | ± 8.00 percent |
| **Redmond** | 132 | ± 8.75 percent |
| **White Center** | 174 | ± 7.50 percent |
| | | |
| **Individual Survey** | | |
| **All individuals** | 600 | ± 4.25 percent |
| **Kent East Hill** | 190 | ± 7.25 percent |
| **Redmond** | 184 | ± 7.50 percent |
| **White Center** | 225 | ± 6.75 percent |
| **Activity Diary** | | |
| **All individuals** | 908 | ± 3.25 percent |
| **Kent East Hill** | 308 | ± 5.75 percent |
| **Redmond** | 256 | ± 6.25 percent |
| **White Center** | 343 | ± 5.25 percent |

**Table 65: Margin of Error of Survey Results**

Possible biases include a lower response rate among houses with unlisted telephone numbers, because these households were contacted by letter only, and a lower response rate among households with shift workers, since the majority of telephone calls were made during the evening. However, the research team concluded that there was no reason why residents with unlisted numbers should differ from the rest of the sample in terms of characteristics significant to the study, and at least one telephone call was made to a household during the day in order to attempt contact with those away in the evenings, before the contact effort was discontinued after eight calls.

## 2. Validation of Sample

When comparing the study sample to the census population, it is important to keep in mind both the margin of error of individual and household measures in the sample, and the fact that the actual study population differs somewhat from the community population. As noted above, survey requirements restricted participation to individuals between 6 and 65 years old, who are able travel outside the home and complete a survey in written English, and who live in households with fewer than five members 6 to 65 years old (excluding group living establishments).

### a) Comparison of Census and Survey Individual Mode Choice for the Journey to Work

A comparison of mode choice for the journey to work as reported in the census and as reported in the two day community travel diary are shown in Table 66 and Table 67 below.

| | Drove Alone | Carpool | Transit | Bicycle | Walk | Other |
|---|---|---|---|---|---|---|
| Kent | 75% | 17% | 5% | 0% | 2% | 1% |
| Redmond | 80% | 11% | 5% | 1% | 3% | 0% |
| White Center | 67% | 17% | 12% | 0% | 2% | 1% |

**Table 66: Census Reported Mode Share for the Journey to Work**

| | Drove Alone | Carpool | Transit | Bicycle | Walk | Other |
|---|---|---|---|---|---|---|
| Kent | 70% | 14% | 4% | 1% | 11% | 0% |
| Redmond | 73% | 11% | 5% | 2% | 8% | 1% |
| White Center | 71% | 17% | 3% | 1% | 8% | 0% |

**Table 67: Trip Diary Reported Mode Share for the Journey to Work**

The most significant difference between mode to work for the sample and the population is the substantially higher walk mode share among the survey sample. In Kent, this increase comes at the expense of lower drive alone and carpool shares relative to the census. In Redmond, the drive alone share is also reduced, and in White Center the transit mode share is reduced in the sample compared to the census. Two biases in the survey process may have led to this difference. First, there may be an element of self selection in the sampling process that resulted in increased participation among individuals who walk more. The survey drew partially on participants in the Neighborhood Quality of Life Study, and these individuals may have gained a heightened sense of the importance of walking and physical activity through that study. Also, individuals who are aware of transportation, community quality of life and physical health issues may have been more inclined to participate in a study seeking to understand such issues.

Second, the sampling process purposefully selected study areas which contained central commercial and office areas which were within walking distance of a large number of households. This likely meant that households within walking distance of work were over-sampled relative to their actual presence in the communities under study, which could have led to elevated walk to work trip rates. To test this possibility, sample mode choice for the journey to work was recalculated, this time excluding all cases where the trip to work was found to be less than one mile long. Results of this analysis are shown in Table 68 below.

| | Drove Alone | Carpool | Transit | Bicycle | Walk | Other |
|---|---|---|---|---|---|---|
| Kent | 77% | 16% | 5% | 1% | 1% | 0% |
| Redmond | 79% | 12% | 5% | 2% | 1% | 2% |
| White Center | 77% | 18% | 3% | 1% | 1% | 0% |

**Table 68: Trip Diary Mode Share for the Journey to Work, Trips Longer than One Mile**

Sample mode choice in this second table is much closer to that reported in the census data, with the exception of White Center transit mode share. This may be related to an upward income bias in the sample influencing rates of automobile ownership among sample households. The number of vehicles available to households is shown in Table 69 and Table 70 below.

## b) Comparison of Census and Survey Vehicle Ownership Rates

| | Average number of vehicles | No vehicles | 2 or more vehicles |
|---|---|---|---|
| Kent | 1.7 | 6% | 54% |
| White Center | 1.7 | 11% | 54% |
| Redmond | 1.7 | 5% | 54% |

**Table 69: Census Household Vehicle Ownership Rates**

| | Average number of vehicles | No vehicles | 2 or more vehicles |
|---|---|---|---|
| Kent | 1.7 | 3% | 50% |
| White Center | 2.0 | 4% | 56% |
| Redmond | 1.8 | 2% | 61% |

**Table 70: Sample Household Vehicle Ownership Rates**

Note that while Table 69 and Table 70 show that the average number of vehicles per White Center households in the sample is comparable to that reported in the census (given the margin of error), the number of households reporting no vehicle ownership in the sample is considerably lower than in the census. It is likely that an income bias in the sample has selected out households without cars, and so has, in effect, selected out households that are more likely to use transit for the journey to work. Further indirect evidence for an income bias in the sample is provided through a comparison of census and sample findings on dwelling type.[5]

### c) Comparison of Census and Sample by Dwelling Type

As shown in Table 71 below, single family homes are over-represented in the sample compared to the census. A primary cause of this over-representation is likely the fact that the survey team had access to fewer telephone numbers for people living in multi-family dwellings. However, it is also likely that sample income bias has also played a role: one would expect that survey requirement that households contain fewer than five members between ages six and 65 would have reduced the proportion of single family homes in the sample relative to multi-family ones; the fact that they are not so reduced reinforces the argument that the sample is biased towards higher income households that can afford their own houses.

| | Census | | Sample | |
|---|---|---|---|---|
| | Single Family | Multi-Family | Single Family | Multi-Family |
| Kent | 24% | 76% | 41% | 59% |
| White Center | 62% | 38% | 82% | 18% |
| Redmond | 35% | 65% | 61% | 39% |

**Table 71: Census versus sample household dwelling types**

### d) Comparison of census and sample by gender

Differences in gender percentages reported in the survey versus those found in the population fall within the margin of error of survey results, as shown in Table 72 below.

| | Census | | Sample | |
|---|---|---|---|---|
| | % Male | % Female | % Male | % Female |
| Kent | 43% | 57% | 49% | 51% |
| Redmond | 50% | 50% | 49% | 51% |
| White Center | 47% | 53% | 50% | 50% |

**Table 72: Census versus sample comparisons of gender distribution**

### e) Comparison of Census and Sample by Age

As shown in Table 73 and Table 74 below, in all three communities the sample strongly under-represents the population in the 18 to 29 year old age range. It also shows moderate under-representation of the 30 to 39 year old age range, and over-representation of older age ranges.

---

5 The Household Questionnaire did not ask for data on household income. However, survey completion rates are often biased towards higher income segments of the population, and, as outlined below, there is substantial indirect evidence that such a bias exists in the current sample.

| | | 18 - 21 yrs | 22 - 29 yrs | 30 – 39 yrs | 40 - 49 yrs | 50 - 64 yrs |
|---|---|---|---|---|---|---|
| Kent | | 10% | 22% | 29% | 23% | 17% |
| Redmond | | 7% | 22% | 29% | 23% | 20% |
| White Center | | 8% | 18% | 25% | 25% | 23% |

Table 73: Census age distributions (weighted proportions in the sample age range)

| | 16 - 17 yrs | 18 - 21 yrs | 22 - 29 yrs | 30 - 39 yrs | 40 - 49 yrs | 50 - 64 yrs | 65+ yrs |
|---|---|---|---|---|---|---|---|
| Kent | 1% | 2% | 8% | 26% | 35% | 27% | 1% |
| Redmond | 2% | 2% | 11% | 22% | 30% | 30% | 1% |
| White Center | 1% | 2% | 10% | 19% | 26% | 41% | 1% |

Table 74: Sample (from the Individual Questionnaire, completed by those 16 to 65 years old)

Several factors may explain under-representation of younger age groups. First, in the case of 18 to 29 year olds, it is likely that the initial survey eligibility requirement that all household members must agree to participate for the household to be eligible for the study had some influence. This age group is most likely to contain households of unrelated adults in shared living conditions, and this heterogeneity may have led to lower levels of participation agreement among all household members, thus leading to exclusion from the study.

Second, given that individuals in this age group are more transient than those in older age groups, it is quite likely that the marketing company which provided the survey team with contact information had access to fewer current and correct telephone numbers for this age group. Since recruitment rates were considerably higher for households for which telephone numbers were available compared to those without (20 percent to 2 percent), this likely led to lower rates of recruitment in these age groups.

Third, study requirements that households contain fewer than five members between ages six and 65 would have selected out households containing two young to middle aged adults with three or more young children.

Over-representation of older age groups also supports the argument that there is an income bias in the sample, since older working individuals generally have higher earning potential than younger ones.

### f) Comparison of the Census and Sample on Ethnicity

As Table 75 and Table 76 below show, when compared to the community populations the sample is clearly-over represented in terms of White individuals, at the expense of other ethnic groups.

| | White | Black | Native American | Asian | Hispanic | Hawaiian/ Pacific Islander | Other |
|---|---|---|---|---|---|---|---|
| Kent | 59% | 11% | 1% | 8% | 10% | 1% | 11% |
| White Center | 46% | 7% | 2% | 19% | 11% | 2% | 13% |
| Redmond | 74% | 2% | 1% | 9% | 8% | 0% | 7% |

Table 75: Census Ethnic Distribution

| | White | Black | Native American | Asian | Hispanic | Hawaiian/ Pacific Islander | Other |
|---|---|---|---|---|---|---|---|
| Kent | 81% | 3% | 1% | 5% | 3% | 2% | 5% |
| White Center | 79% | 3% | 2% | 4% | 4% | 0% | 7% |
| Redmond | 92% | 2% | 0% | 2% | 2% | 1% | 2% |

**Table 76: Sample Ethnic Distribution**

Survey language requirements were likely the primary cause of under-representation of immigrant ethnic groups. Language barriers were cause for elimination of 178 and 179 households in Kent East Hill and White Center respectively, but only 13 households in Redmond. Likewise, an income bias in the sample may also explain some under-representation of non-White groups.

Furthermore, an advisor to the NQLS project has suggested that non-White ethnic groups are harder to reach by phone, because many non-White households do not have answering machines and may be hesitant to answer unsolicited telephone calls.[6] While the non-response rates of households without telephone numbers was fairly consistent across the 3 neighborhoods, the non-response rates of households with telephone numbers was higher in Kent East Hill and White Center, where the minority populations are higher.

Finally, it is also possible that survey requirements that households contain fewer than five people between six and 65 may have also led to under-representation of households in some ethnic groups. Elimination based on household size was especially frequent in White Center, where 26 households in total were rejected for this reason.

### g) Summary of Sample Validation

In summary, the sample collected for the three communities in the case study is older, is more likely to live in single family homes and is more likely to be White than the general population for those communities. In addition, in White Center the sample is more likely to own at least one vehicle, and to drive rather than take transit to work for work trips over one mile in length. It is interesting to note that similar biases were reported in the Puget Sound Household Travel Survey (PSRC 1999). That study generated a four county sample with 76 percent of households in single family dwellings, 89 of individual respondents reporting White ethnicity, and only 5 percent of households with no vehicles – all substantial deviations from the four-county census findings. Furthermore, the Puget Sound Study also over-represented households with incomes greater than $45,000, and under-represented households with incomes less than $35,000, a pattern which is suspected to be the case with the study described here as well. In short, it is likely that the biases present in the current study sample are similar to those found in other regional travel surveys.

6 Personal conversation with Kelli Cain, NQLS Project Manger, June 2004.

# III. Case Study Existing Conditions

The goal of this section of the case study analysis is to create a picture of current conditions in the three communities. As shown in Figure 39 below, it aims to provide a description of the communities along a number of inter-related dimensions: the built environment, attitudes, demographics, and travel behavior.

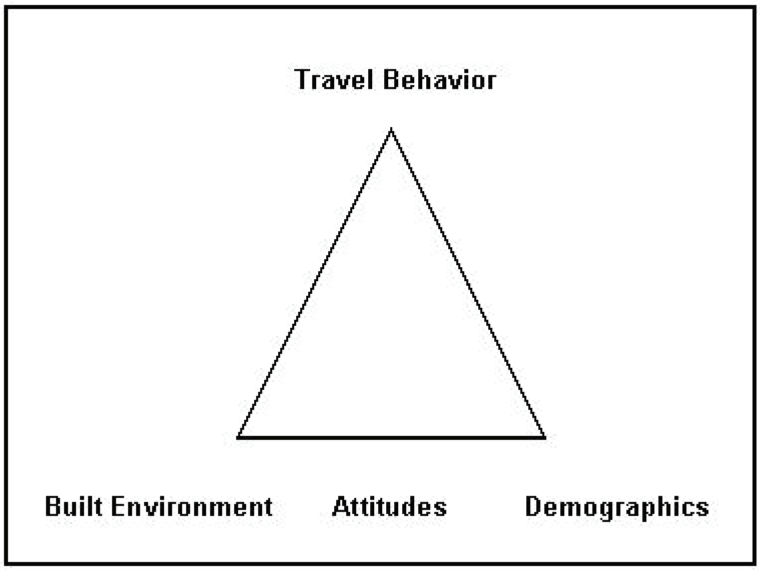



**Figure 39: The primary components of the case study analysis**

The case study descriptions work on the premise that community level travel behavior is a product of the built environment, which constrains travel choices, and demographics, which generates different travel requirements for different segments of the population. In addition, travel behavior is also mediated by attitudes and perceptions about walkability, accessibility, safety, etc., which influence and further constrain available choices. Given this premise, this section will first present a description of each case study location, including a brief summary of historical development, a review of community demographics, a description of the local transportation system and its regional context, and a review of the built form of the urban environment. Where relevant, survey respondents' attitudes and perceptions of community characteristics are also presented. A brief comparison of the three communities' transportation systems, land uses and urban development patterns, and "main street" profiles will summarize the context for each community, before a comparison of travel behavior in the three communities is presented.

Note that the review of existing conditions and recommendations for urban design changes presented here are only a summary of the more detailed findings presented in Appendix V, the Case Study Report.

## A. White Center

### Location

Located 12 miles south of downtown Seattle, White Center is surrounded by steep hills and sandwiched between the Duwamish River and Puget Sound. It lies partly within the City of Seattle and partly in unincorporated King County. Its location is shown in Figure 40 below.

### Historical Development

White Center was first platted in the early 1900's. The first formal business to open in White Center was the Oak Park Grocery, which was established in 1908 at the northwest corner of what is now 16$^{th}$ Avenue and 107$^{th}$ street. In 1912, a streetcar line opened along 16$^{th}$ Avenue with service between Seattle and Burien. By 1925 a substantial commercial center had developed along 16$^{th}$ Avenue around Roxbury. In 1931, King County paved the south side of Roxbury Street, and the streetcar line was shortened to terminate there. After being cut off from downtown Seattle by a landslide over the tracks, streetcar service to White Center was shut down in 1934 and replaced by bus service.

During and after World War II the area experienced strong growth as a bedroom community for workers at the Boeing Plant and other industrial sites in the nearby Duwamish industrial flats. Many of these workers' houses still exist in close to their original form. These houses are smaller than the average in King County – only 800 square feet each. During this time White Center's growth was focused on development of housing stock, with little investment in public spaces.

The community has a reputation as an entertainment destination that dates to the early 1900's, when taverns, nightclubs, card rooms, pool halls, and a boxing ring located just outside of Seattle city limits in unincorporated King County to avoid City laws prohibiting such activities. That reputation persists today: White Center's "main street", 16th Avenue SW, currently has four taverns, one licensed restaurant, two nightclubs and three adult bookstores.

In 1959, White Center refashioned the 16th Avenue commercial district into a 'traffic mall.' Street improvements included a 25 mph speed limit and concrete islands topped with shrubs and angled parking, which increased parking spaces by 80 percent. Unfortunately, these improvements did little to stop the district's decline during the 1960's. As south King County grew rapidly during this period, business was drawn away from White Center by new commercial facilities in Burien as well as by the Southcenter and Westwood Village Malls. The large Boeing layoff in 1971 hit White Center hard and it is only in the past decade that White Center has begun to see some reinvestment.

In addition to suffering from competition with more prosperous neighboring commercial centers and loss of jobs at its largest employer, White Center has been constrained economically and socially by its split jurisdiction. This split has meant that acquiring public services – especially adequate police services – and amenities as a unified community is difficult. The influence of different jurisdictions is visible in the maintenance and configuration of the street realm; street trees are present on Delridge within the Seattle City Limits, but are lacking on 16th within unincorporated King County.

As real estate prices and traffic problems increase in other areas of Greater Seattle, White Center's reputation is gradually changing as others recognize the value present in its relatively large residential lots, inexpensive housing costs and fifteen-minute commute to downtown Seattle. In addition, as the regional diversity grows, its multicultural population is increasingly seen as an asset and attraction.

Today, automobile services, ethnic groceries, restaurants and bars, and professional and neighborhood services dominate the White Center economy. The district has especially attracted immigrant entrepreneurs from Asia, the Pacific Islands, and Central America. According to the Puget Sound Business Journal, more than 30 specialty shops for racial and ethnic groups are now doing business in White Center. Inexpensive ethnic groceries, specialty shops, and restaurants have helped to create a value-destination reputation that was previously based on a concentration of thrift stores. Indeed, many White Center businesses claim that regular customers travel from up to thirty miles away.

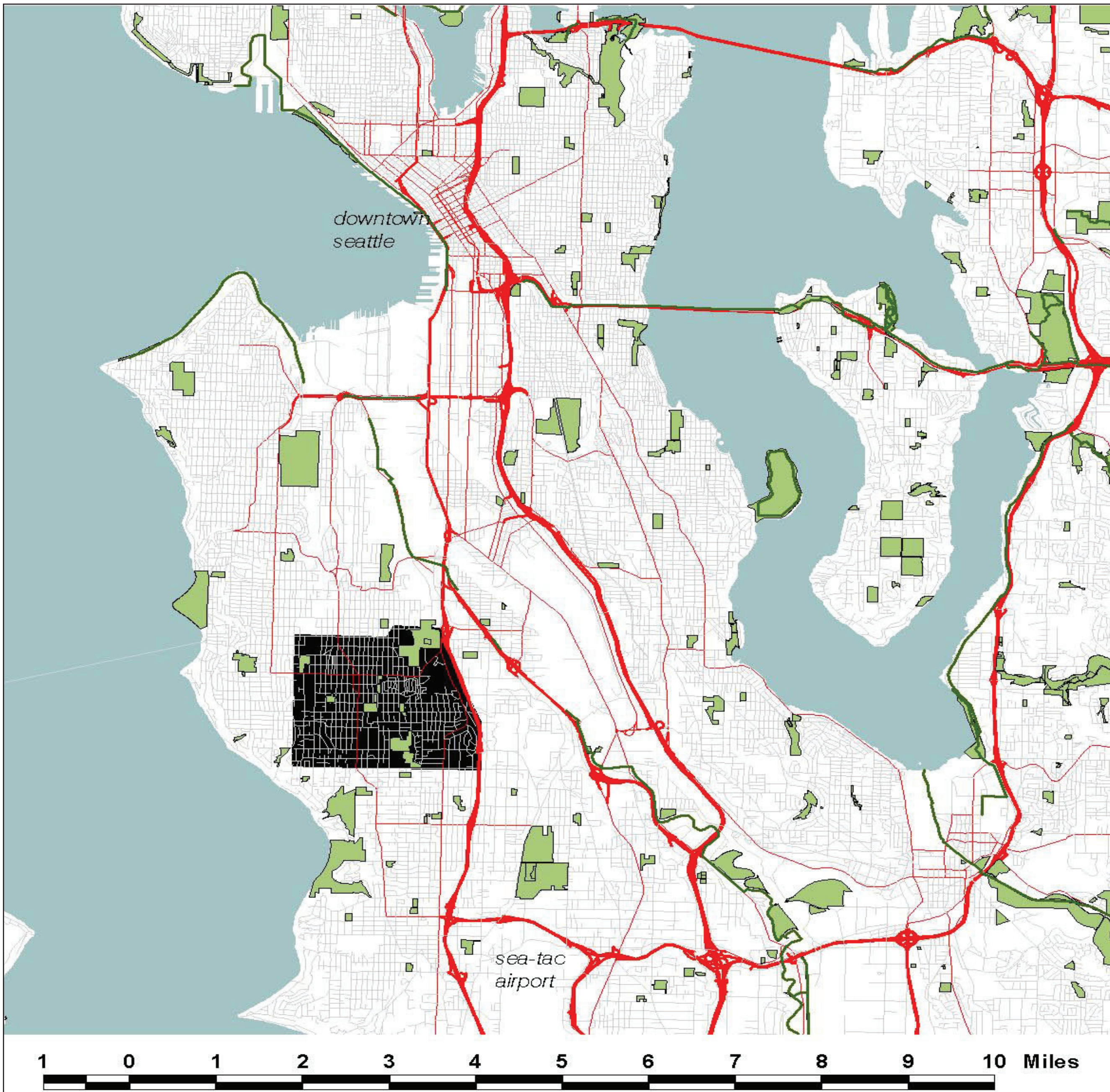



**Figure 40: White Center in its Regional Context**

White Center is increasingly viewed as a case study for urban renewal and numerous governmental and non-governmental organizations both inside and outside the community are investigating the area's potential. A substantial grant from the Annie E. Casey Foundation has, over the past few years, helped to create a network of leaders for the various ethnic communities and helped to initiate the White Center Community Development Association (Seattle Times 2003). Currently there is also a high level of public investment in the community.

### Demographics

White Center was once known as 'Rat City' – a nickname of uncertain origin which nonetheless hints at the community's traditional status in Greater Seattle. White Center has historically been a poor, inner-ring suburb that served the needs of blue-collar workers and low-income families, and it has the lowest median income of the three case study sites. There is a range of incomes within White Center itself, however, with the lowest incomes found in the vicinity of a major public housing project, and the highest incomes in the southwest corner of the case study site.

Compared to King County as a whole, White Center has a higher crime rate, a higher percentage of families living in poverty, fewer students who finish high school, and a higher percentage of mothers who receive inadequate prenatal care.

White Center is one of the most ethnically diverse communities in King County – 54 percent of its population is non-White – and it has become a gateway community for immigrants in recent years. Recent immigrants are attracted to this community because its low housing and rental prices provide a place where new residents can get a start in their adopted country. The community includes people from Latin America, Southeast Asia, East Africa and Eastern Europe, resulting in a vital, cosmopolitan feel. Many new immigrants start small businesses in White Center -- it has been called "a suburban version of Seattle's International District" (PSBJ 2002). These diverse populations tend to be located around the commercial core of White Center, in the King County Housing Authority project, and in other concentrations of multifamily housing.

White Center also has the largest average household size of the three case study areas – 2.6 persons per household – which may be related to its large immigrant population. It also has a relatively high rate of housing occupancy – 96.5 percent – compared to Kent and Redmond. Of the three case study sites, White Center also has the oldest median date of housing unit construction, reflecting the fact that it is an older residential community, with its beginnings in the early 20$^{th}$ century.

### Transportation System

White Center has easy access to the SR 509 freeway, providing an efficient vehicle link to downtown Seattle and Sea-Tac Airport.

The age of the community is reflected in the design of its street network: White Center is a classic, early 20th Century 'streetcar suburb' with a gridiron layout of streets and compact blocks, many with back lanes. White Center lies partly within the City of Seattle, although the more substantial portion of the case study area is within unincorporated King County. This jurisdictional split is evident in the community's pedestrian infrastructure: most streets within the boundary of the City of Seattle possess sidewalks, whereas within King County only arterial streets and those proximate to the commercial core around 16th Avenue SW have sidewalks.

While there is a designated network of bike routes, mainly along arterial roads, none of these routes include marked bicycle lanes or signage.

### Land Use and Urban Form

White Center possesses a traditional, somewhat strict separation of land uses. Commercial and retail uses are found along the 16th Avenue SW corridor, in the Westwood Village shopping mall, and in a small cluster along 1st Avenue SW. White Center contains a wide range of land uses and community services and has numerous parks. There is little to no residential density to be found in the commercial areas, and there are few, if any, mixed use developments. Overall, White Center has a relatively low residential density. Most of the community consists of single family homes. The low residential density within and close to three commercial areas reduces the number of residents within walking distance of retail destinations.

White Center has a high intersection density, and a high degree of street connectivity due to its gridiron street network. However, because many of White Center's streets lack sidewalks, the value of that connectivity for pedestrians is reduced. Also, many streets lack formal drainage systems (i.e. a curb and gutter system) further reducing separation of pedestrian walking space from the roadway. In addition, the lack of a formal drainage system increases the amount of standing water during the wetter months, which creates problems for pedestrians and cyclists. The community also lacks off-street walking and cycling paths.

In summary, White Center has many assets, including a good amount of park space, a gridded street network with high connectivity, and an ethnic diversity of residents that increases community vitality. However, it also has specific deficiencies, including a lack of sidewalks and pedestrian routes, lack of people living in and adjacent to commercial areas, and a lack of an identifiable center. The community has 'good bones' in the form of a well-connected network of streets, but it lacks the pedestrian infrastructure and the required residential and commercial density that would help promote walking.

### Survey Respondent's Comments on Willingness to Walk to Destinations and Perceptions of Community Walkability

Approximately 95 percent of White Center survey respondents indicated that the availability of well lit streets was a moderate to very important positive influence on their decision to walk in their neighborhood; respondents also reported that they felt current lighting levels were adequate. The next most important consideration was the presence of sidewalks, with 85 percent indicating that this was a moderate to very important influence on their decision to walk. A majority of White Center residents were strongly dissatisfied with the quality of existing sidewalks, and they also noted that the system is not continuous.

Approximately 80 percent of respondents ranked the proximity of shops and services as important influences on their decision to walk, and a majority reported that they have shops, services and restaurants within walking distance of home. Seventy percent of respondents reported that proximity to transit was also an important positive influence on the decision to walk.

Ninety-one percent of respondents in White Center reported that crime was a moderately to very important negative influence on their decision to walk, although respondents were evenly split on whether or not they actually feel safe from crime when walking in their neighborhood. Seventy-five percent of White Center respondents reported that traffic and busy intersections were important negative considerations in the decision to walk in their neighborhoods. A majority of White Center respondents felt that their neighborhoods currently were not safe from traffic, and they were evenly split on the safety of their street crossings.

Finally, 70 percent of respondents in White Center felt that a lack of places to walk to was an important influence on their willingness to walk, and a strong majority thought that there were steep hills in the community that reduce walkability.

## Respondent Comments on Community Satisfaction from the Survey Research

### *Reasons for Choosing the Community*

White Center respondents indicated that affordability was a very important factor in their choice of home community, and that access to employment and schools and safety from crime were also important considerations. In contrast, three quarters of all respondents indicated that ease of walking was not at all or at best only a moderately important consideration in choice of community. As with the other two communities, access to public transit and low transportation costs were not rated as important considerations in choice of community.

### *Overall Satisfaction with the Community*

A majority of White Center survey respondents showed strong satisfaction with current levels of highway access, commute times to school and work, and access to shopping. A large number of respondents also indicated they were strongly satisfied with access to public transit, although a fair number of respondents also declared themselves neutral on this last issue. A large number of respondents declared themselves moderately satisfied with the number of friends they have and people they know in the community, the ease of walking in the community, the number of local restaurants, levels of traffic noise, and the overall quality of the community as a place to live.

Respondents were more or less equally split between satisfaction and dissatisfaction in terms of the number of crosswalks and the easy of cycling in the community. A majority of White Center respondents reported themselves more dissatisfied than satisfied with the quality of community schools, access to entertainment, and the quality of the community as a place to raise children.

Finally, a majority of residents reported themselves strongly dissatisfied with levels of traffic and safety from the threat of crime in the community.

## B. Kent East Hill

### Location

Kent East Hill is located to the east of Seattle in the valley of the Green River, as shown in Figure 41 below.

### Historical Development

The first White settlers arrived in the Kent area in 1853 and established a claim southeast of what is now downtown. The community first made its name as a center for hops, but by the time it incorporated in 1890 the agricultural focus was shifting to grass and dairy farming, and by the 1920's Kent had become a center for vegetable truck farming. Japanese immigrants farmed much of the valley from the 1920's until they were evicted and interned in 1942. Less than one third of the original Japanese population returned to resume farming, precipitating a gradual turnover to industrial uses. Valley lands were attractive to developers due to their flat terrain and proximity to major rail lines, highways and Sea-Tac airport, and warehousing and distribution became an increasingly important part of Kent's industrial development during the post war period.

Kent's character has changed since the 1960's. Before 1960, 90 percent of Kent's housing stock was composed of single family dwellings, but by 1992 only 32 percent was still in that form. The population of Kent has also grown significantly in the past few decades; between 1970 and 1990, Kent's population more than doubled, and between 1990 and 2000 it doubled again. This growth is expected to continue for the next 20 years, although not at such a fast rate. As the City of Kent's comprehensive plan update states, "While this growth has brought some benefits … it has also produced urban sprawl, congested streets, and increased demand for community and human services, and threatened environmentally sensitive areas" (Kent 2001). Kent East Hill began to develop in the 1960's, with commercial development along Kent-Kangley Road. It is a new community, with a median housing unit construction date of 1980.

### Demographics

Kent East Hill is a suburban neighborhood with a population of about 10,000. It has a median household income of $46,985 which is higher than White Center, but lower than Redmond. Kent East Hill has a relatively young population, with a median age of 30.7 years, the youngest of the three case study sites. It is also surprisingly ethnically diverse: 42 percent of its population is classified as 'non-White'. Of the three case study sites, it has the lowest average household size, at 2.4 persons per household.

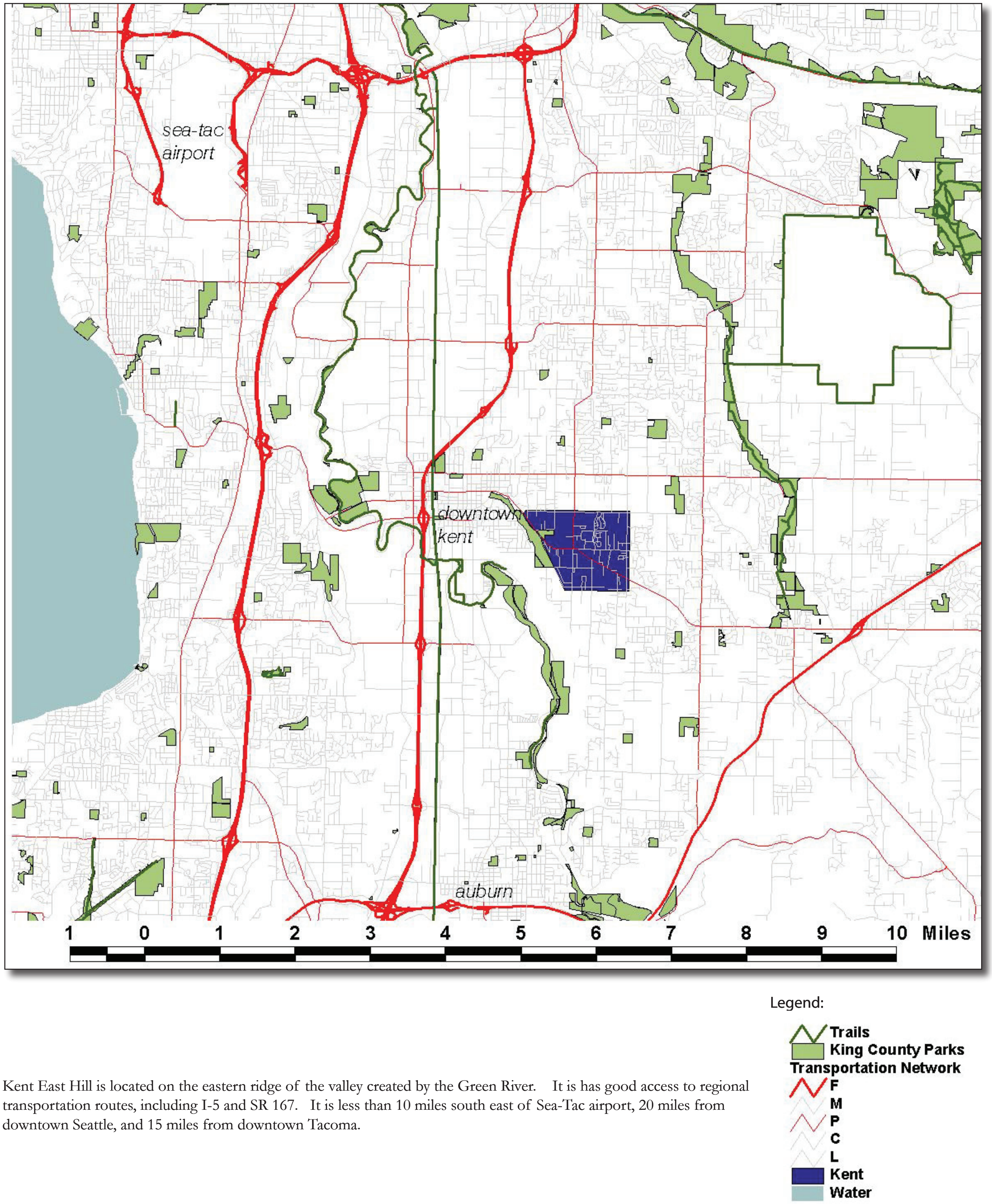
### Transportation System

Kent East Hill is located approximately one mile from the SR 167 freeway, and is connected to adjacent neighborhoods by a number of major arterials. The urban form of Kent East Hill is defined by the intersection of three major arterials: Kent-Kangley Road, 256th Street and 104th Avenue. Kent has a small network of public roads, with many private roads taking the place of local streets. Most of the private roads are self-contained systems – they do not create a connected network, but instead are isolated mini-networks, often with only one or two outlets to a major arterial or collector. There is an incomplete and disconnected network of sidewalks and pedestrian facilities, and while there are designated bicycle routes along the major arterials, there are no bike lanes or signage for these facilities. Most of Kent East Hill's roads and streets have been constructed in the past 20-30 years using street design standards which were established for the efficient mobility of automobiles; pedestrian and bicycle facilities are minimal at best. Streets and travel lanes are wide so that cars can move at high speeds, and there is very little on-street parking or landscaped buffers to provide a sense of separation between cars and pedestrians.

Kent East Hill has a relatively good network of bus routes which provide connection to downtown Kent and destinations north and south.

### Land Use and Urban Form

Kent East Hill possesses an urban form typical of many suburban clusters that have developed in the region since the 1960's. This form consists of a core of local retail – usually in the form of two or more suburban strip malls – centered around a pair of intersecting arterials. In a typical suburban cluster this retail hub is then surrounded by high density multifamily housing developments, each with its own driveway or system of driveways, which separate it from surrounding properties. This ring of multifamily development is then often surrounded by single family subdivisions.




Kent East Hill is located on the eastern ridge of the valley created by the Green River. It is has good access to regional transportation routes, including I-5 and SR 167. It is less than 10 miles south east of Sea-Tac airport, 20 miles from downtown Seattle, and 15 miles from downtown Tacoma.

**Figure 41: Kent East Hill in its Regional Context**

However, despite the concentration of commercial uses in its core and the nearby presence of high density housing, the development pattern of Kent East Hill as a whole, as well as the site design conditions of the multifamily housing developments, make walking difficult if not impossible. There are no direct pedestrian routes from the multifamily housing developments to the retail core, and the pedestrian facilities which do exist are minimal at best. As a result very little of Kent East Hill's high density housing is within a quarter mile actual walking distance of the commercial core, though it is maybe less than a quarter-mile "crow fly" distance from the core. Furthermore, the commercial core of Kent East Hill has quite a coarse grain of development; retail buildings are very large, and are often surrounded by large parking lots. The large commercial blocks in the core and the abundance of poorly linked private roads result in low connectivity and low walkability.

The City of Kent has recently completed updates to its Comprehensive Plan which explicitly address some of the problems described above. Planning goals articulated in this update include emphasis on future growth and development which minimizes sprawl, mixed use development, the development of a transportation network which promotes a variety of mobility options, and the provision of public facilities, especially for medium and high density residential developments.

In summary, Kent East Hill does posses some positive assets, including some of the most affordable housing in Greater Seattle; an ethnically diverse population; some unimproved public right of ways which could be used for pedestrian and bicycle infrastructure; and nearby open space resources such as Mill Creek Park. However, the community is also faced with a number of deficiencies, such as a lack of accessible park space within its boundaries, low street connectivity, and low residential densities in commercial areas.

### Survey Respondents' Comments on Willingness to Walk to Destinations and Perceptions of Community Walkability

As in White Center, approximately 95 percent of respondents indicated that the availability of well lit streets was a moderate to very important positive influence on their decision to walk in their neighborhood, and respondents reported that they felt current lighting levels were adequate.

The next most important positive influence was the presence of sidewalks, with 88 percent of Kent East Hill respondents indicating this was a moderately to very important influence on the decision to walk. In terms of the current quality of sidewalks in the community, a slight majority of Kent East Hill residents indicate that they are satisfied with the quality of their sidewalks, though they note that they are not continuous.

As with White Center, 80 percent of respondents also ranked the proximity of shops and services as important influences. Of all three communities, Kent East Hill had the largest majority of respondents agreeing with the statement that they have shops, services and restaurants within walking distance of home. In Kent East Hill only 65 percent of respondents felt that proximity to transit was an important influence on their decision to walk.

Crime was a moderate to very important negative influence on the decision to walk for 85 percent of respondents in Kent, with a small majority of respondents reporting that they actually feel safe from crime when they do walk. Eighty-two and 84 percent of Kent East Hill respondents reported that traffic and busy intersections respectively were important negative considerations in the decision to walk in their neighborhoods. A large majority of Kent East Hill residents reported feeling that their neighborhood was not safe from traffic, although a small majority reported feeling that they had safe street crossings.

Finally, 70 percent of respondents in Kent East Hill felt that a lack of places to walk to was an important influence on their willingness to walk, and they were evenly split between agreement and disagreement on whether or not steep hills were a constraint on walking in the community.

## Respondent Comments on Community Satisfaction from the Survey Research

### *Reasons for Choosing the Community*

The greatest number of respondents agreed that the most important reason for choosing Kent East Hill was its affordability. A majority of respondents also indicated that being close to jobs and school, and safety from crime were moderately to very important factors and that access to shops and services and freeways were also important factors. Clearly, however, respondents are thinking in terms of vehicle access when they rate the importance of these mobility and access factors in choosing their community, because a large majority also agreed that access to public transit was not an important factor in choosing Kent East Hill for their home, and as with White Center, three quarters of all respondents indicated that ease of walking was at best of only low importance.

### *Satisfaction with the Community*

Kent East Hill residents reported themselves very satisfied with their commute times to school and work, the quality of community food stores and their access to retail shops. Though there was a broader range of opinion, they also reported themselves generally satisfied with highway access, the number of friends and people they know in the community, community walkability, access to arts and entertainment, traffic noise, the quality of restaurants, and the quality of the community as a place to raise children and live. Respondents were generally satisfied with transit service as well, although, as with White Center and Redmond, a large number of residents were neutral on the topic. Respondents were also neutral on the quality of community schools.

Finally, residents were evenly split between satisfaction and dissatisfaction on safety from crime in the community, and were generally dissatisfied with traffic volumes, ease of biking and the number of crosswalks in the community.

## C. Redmond

### Location

As shown in Figure 42 below, Redmond is located 11 miles north east of Seattle and four miles east of Kirkland, at the north end of Lake Sammamish and along the valley bottom and slopes of the Sammamish River valley.

### Historical Development

When European settlers first arrived in the area in the 1870's they found so many salmon that they first called the place Salmonberg. Twelve years later, the town was re-named after its postmaster of the day.

During the 1880's loggers who poured into the area built lumber and shingle mills. In 1888 the Seattle Lake Shore and Eastern Railway reached the town. In its logging heyday, the town included a stagecoach office, saloons and hotels, blacksmiths and eateries. Redmond was incorporated in 1912, and logging began to fade shortly thereafter, as the last of the area's old growth forests were harvested. In the following decades agriculture, specifically dairy and chicken farming, became the area's mainstay.

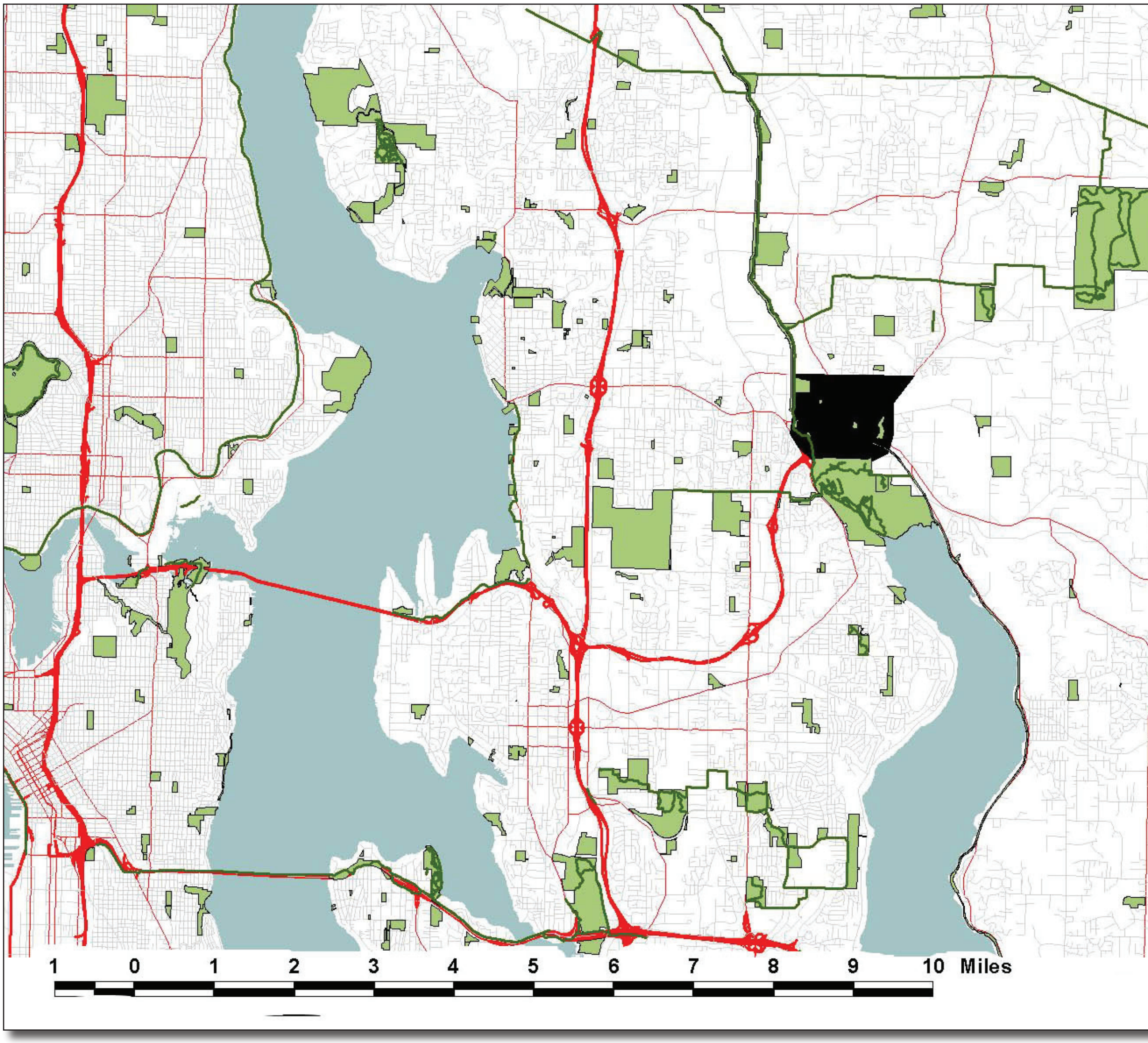
With the completion of the Evergreen Point floating bridge across Lake Washington in 1963 Redmond became directly connected to Seattle, contributing to significant suburban growth in the 1960's and 1970's. Growth accelerated with the completion of SR 520 and the annexation of the Overlake area to accommodate the high tech industries locating there. With the arrival of Microsoft and many other software and digital companies in the early 1980's, Redmond grew rapidly and is now home to the head offices of many major corporations. The city is a major regional employment center, with more jobs than residents. It is a very prosperous community, with a much higher median household income than the average for King County or the other two case studies described here.

Substantial changes have happened to the built environment of Redmond over the past 10 years, including the development of Redmond Town Center south of the historic downtown core, the creation of a new municipal "campus" northwest of the downtown core, new shopping complexes at the north end of central Redmond, and infill multifamily housing northwest of downtown. Redmond also has an extensive park system with over 1,350 acres of parkland and over 25 miles of trails.

Redmond is currently in the process of completing a series of housing and traffic amendments to its 2002 Comprehensive Plan. The housing amendments seek to "increase the supply and diversity of housing in Redmond not only to provide more opportunities for people to live closer to work, but also to meet better the needs of people of various ages and incomes, from young adults to seniors."

The traffic amendment "emphasizes land use and transportation strategies to reduce traffic impact associated with more growth" (Redmond 2002).

Designated as a regional urban center under Vision 2020, Redmond is slated to receive substantial residential and job growth over the next 20 years. Indeed, Redmond currently has both greenfield and infill developments underway, including an array of mixed use developments and greenfield projects which advertise themselves as transit oriented developments and walkable places to live. Redmond is a community that has a lot going for it: economic vitality and diversity, abundant recreational facilities, and an emerging urban milieu. Its challenge will be to manage this continued growth so that it produces a built environment that is supportive of walking and biking, and accessible to a wide public.




Redmond is located at the north end of Lake Sammamish, along the lowland valley of the Sammamish River. It is at the end of SR 520, and about 11 miles from downtown Seattle. It is close to the Eastside communities of Kirkland and Bellevue.

**Figure 42: Redmond in its regional context**

## Demographics

Redmond is the wealthiest of the three case study sites, with a median household income of $56,206. This is not surprising given the significant presence of high tech industry in the area. It is also the oldest case study site, with a median age of 37.7, and the least ethnically diverse, with approximately 34 percent of the population being classified as non-White. Redmond is also the least populous of the three sites; within the case study boundaries the 2000 census population was 4,314. Redmond's average household size is 2.6, which is higher than Kent East Hill but lower than White Center. Finally, despite the fact that Redmond was incorporated as a town in the early 1900's, the median date of housing unit construction is 1981; this discrepancy reflects the explosive growth Redmond has seen over the past 20 years.

### Transportation System

Redmond is well connected to the rest of King County by the SR 520 freeway. A grid of arterials and major routes connect downtown Redmond to outlying suburban developments and adjacent communities. The street network in much of Redmond, especially on the valley floor, is essentially a grid system, although the majority of its block sizes are rather large. Redmond has a fairly compete sidewalk system and it has a network of both marked and unmarked bicycle routes, which includes the regional Sammamish River Trail.

With the exception of one single family neighborhood (Redmond Highlands), it would appear that most of Redmond is well provided with transit service.

### Land Use and Urban Form

Redmond is a collage of urban styles: it has an original late 19$^{th}$ century town core, a 'postmodern' / 'new urbanist' town center (essentially an outdoor shopping mall), areas of big blocked, auto oriented office park and retail development, some early 20$^{th}$ century style platted blocks, and areas of late 20$^{th}$ century single family cul-de-sacs and loops. Current projects may help to link these pieces together into a coherent whole, through infilling with high density residential and mixed use developments.

Redmond appears to have a good range of land uses, and an especially good distribution of restaurant amenities: quite a large portion of the case study area is within a quarter mile walking distance of restaurant destinations. However, Redmond has very little residential use in the commercial core, although this appears to be changing. Redmond's intersection density is mid-way between that of White Center and Kent, and the connectivity of its street network is adequate at best - some blocks are very large, and its single family neighborhoods have limited access routes to the downtown core.

Many of the streets in Redmond, including some of the main commercial streets, display the characteristics of late 20$^{th}$ century traffic engineering and transportation planning: wide travel lanes, no planting strips or buffers, little on street parking, minimal sidewalks, and retail developments fronted with parking lots. These characteristics all make for an unpleasant and unfriendly pedestrian environment. More recent developments, however, have tried to reverse this trend by siting the buildings at the sidewalk edge, providing wider sidewalks, and, in the case of Redmond Town Center, creating narrower streets with on-street parking.

Redmond has many positive assets, including proximity to large regional recreational resources such as Marymoor Park and the Sammamish River Trail, an abundance of employment within the community, a strong and fresh comprehensive plan, a new transportation plan, and a trend towards development of higher density housing close to downtown.

However, it also has some deficiencies that need to be addressed. The old downtown is dominated by the one-way couplet of Redmond Way and Cleveland/Avondale Rd. These are not pedestrian friendly streets because traffic moves too fast and development is stepped back away from the street. In northwest Redmond where new residential developments are being created, the streets are too wide to be intimate. Redmond needs to develop a more refined street hierarchy, so that some of these streets begin to feel more like local streets and less like arterials. There is also a lack of residential density in the old downtown area and in the new town center.

### Survey Respondents' Comments on Willingness to Walk to Destinations and Perceptions of Community

As in Kent East Hill and White Center, approximately 95 percent of Redmond respondents indicated that the availability of well lit streets was a moderate to very important positive influence on their decision to walk in their neighborhood. Redmond respondents showed the strongest satisfaction with current lighting levels of any of the three communities.

The next most important positive influence was the presence of sidewalks, with 91 percent of Redmond respondents indicating this was a moderately to very important influence on the decision to walk. In terms of the current quality of sidewalks in the community, Redmond residents again indicated that they were strongly satisfied, and that there were continuous sidewalks on most streets.

Approximately 80 percent of respondents in Redmond, as in the other communities, ranked the proximity of shops and services as important influences. A majority of Redmond respondents also reported that they have shops, services and restaurants within walking distance of home.

In Redmond only 55 percent considered proximity to transit an important influence on their decision to walk, compared to 70 percent of respondents in White Center.

Only 74 percent of Redmond respondents reported that crime was a moderately to very important consideration, a smaller percentage than in White Center or Kent. A strong majority of respondents from Redmond also reported that they currently feel safe from crime when walking.

Seventy-five percent of Redmond respondents reported that traffic and busy intersections were important negative considerations in the decision to walk in their neighborhoods, and a majority felt that they have safe street crossings and that their neighborhoods are safe from traffic.

Finally, whereas 70 percent of respondents in both Kent East Hill and White Center felt that a lack of places to walk to was an important influence on their willingness to walk, only 65 percent of Redmond respondents felt the same way. In addition, a strong majority in Redmond thought that there were steep hills in the community that reduce walkability.

### Respondent Comments on Community Satisfaction from the Survey Research

#### *Reasons for Choosing the Community*

Redmond respondents indicated that access to employment and school and safety from crime were the two most important factors in choosing their community. They also indicated that affordability and freeway access were very important, and that proximity to open space, proximity to shops and services, walkability and sense of community were somewhat important. Finally, most Redmond respondents indicated that access to public transit and low transportation costs were of little importance in their decision on where to live, and 60 percent indicated that walkability was of little or no importance in their decision.

#### *Satisfaction with the Community*

Redmond respondents showed very high satisfaction with access to highways from their community, with commute times to work and school, with access to retail shops, arts and entertainment, neighborhood walkability, safety from the threat of crime, the quality of neighborhood restaurants and food stores, and the overall quality of the community as a place to live. While still largely positive, respondents showed a broader range of satisfaction with the number of friends and people they know in their community, the ease of biking around the community, the number of pedestrian crosswalks, the quality of its schools, and its quality as a place to raise children. Respondents were also satisfied with access to public transit in Redmond, although a considerable number were neutral on the topic.

Respondents were evenly split between satisfaction and dissatisfaction with traffic noise, but they were generally dissatisfied with traffic volumes.

## D. Similarities and Differences between the Three Communities

### Transportation Systems

Each of the case study areas has easy access to one of Puget Sound's major freeways: White Center to SR 509, Redmond to SR 520, and Kent East Hill to SR 167. Each community has good access to the major transportation corridors in the region. In terms of their internal street network, each case study community contains a basic grid of arterials and collectors; Kent's major roads seem to be spaced the furthest apart.

The vintage of each community is reflected in each of their street network systems: White Center is an early 20th Century classic 'streetcar suburb' – with a gridiron layout of streets and blocks. Redmond has a small core of early 20th century gridiron blocks, and its valley areas also have a grid pattern, but it is full of holes, and needs completion in order to better connect the network. Kent East Hill has a small network of public roads, with many private roads taking the place of local streets. Most of the private roads are self-contained systems, often with only one or two outlets to a major arterial or collector.

While each of the communities has designated bike routes, most of these routes do not include actual facilities such as bike lanes marked on the roadway, separate paths, or signage. Only Redmond has marked bike lanes, but this system is partial and incomplete.

Redmond has a relatively complete network of public sidewalks, but Kent East Hill and White Center do not. Most, but certainly not all, of the streets in White Center that fall within the City of Seattle have sidewalks; on the King County side of the community most streets do not have sidewalks, except for arterials or collectors and streets immediately surrounding the commercial core of 16th Avenue SW and Roxbury. Kent East Hill has only a partial system of sidewalks; most of the major arterials have them, but on 256th Street they end shortly east of 104th Avenue. Some private roads have sidewalks, but most do not. There is little linkage or connection between the private sidewalks and the system of public sidewalks.

### Land Use

The overall land use, residential density and restaurant buffer maps shown in Figure 51 provide a sense of the organization of activities and land uses in the three communities. White Center is shown at a smaller scale relative to the Kent East Hill and Redmond, because it is twice as big. Full size versions of these maps can be found in Appendix V.

The first row of maps shows the distribution of land uses (as opposed to zoning) in the three communities; each color represents a different use, red being commercial, yellow residential, and blue civic or institutional. Even taking into consideration the difference in scale in the maps, it is interesting to note the relative concentration of White Center's commercial land uses into three discrete areas when compared to Redmond or Kent, which have large dispersed commercial areas as indicated by the concentration of red colored parcels. In all three communities however, there is a fairly strict separation between uses, a legacy of modernist planning and zoning as well as contemporary development practices.

The second row of maps in Figure 43 displays residential density, with dark brown being the densest and gray the least dense. The maps reveal that all three case study communities lack any substantial residential density in their commercial areas (as represented by the red areas in the maps in the first row); gray areas in this second row represent land which has less than one dwelling unit per acre. As a result of having little to no residential presence, these commercial areas become 'dead' when the shops and services shut for the day. The lack of a residential presence in commercial areas means that there are no 'eyes on the street' at night, which leads to a perception, and perhaps reality, of lack of safety for pedestrians on the street. Especially in suburban communities such as Kent, the commercial center turns into a sea of empty parking lots at night.

It is also worth noting that all three communities have areas of high density residential development as indicated by the brown areas on the maps in row two, which represent multi-family dwellings; Kent, in fact, displays a higher proportion of multi-family dwellings than single-family dwellings.

The final row of maps in Figure 43 shows quarter-mile network buffers around restaurants in each case study community. These maps reveal the extent of each study area that is within a comfortable five minute walk of a restaurant, and likely commercial shops and services as well. White Center has the highest street connectivity of the three areas due to its gridiron street network, and keeping in mind that this community is presented here at a smaller scale than the other two, shows the largest number of households within a quarter mile walk of a commercial destination. Interestingly, the spread out distribution of restaurants within Redmond's large commercial land area means that of all three case studies, this community has the largest land area within a quarter mile walk of these destinations; however, by comparing the coverage of these restaurant buffers to residential density in the second row of maps, one can see that, with the exception of a few newer high density residential developments in the core, very few households are within a five minute walk of restaurants. Kent East Hill displays essentially the same conditions as Richmond, in that restaurant buffers do not substantially overlap with residential areas.

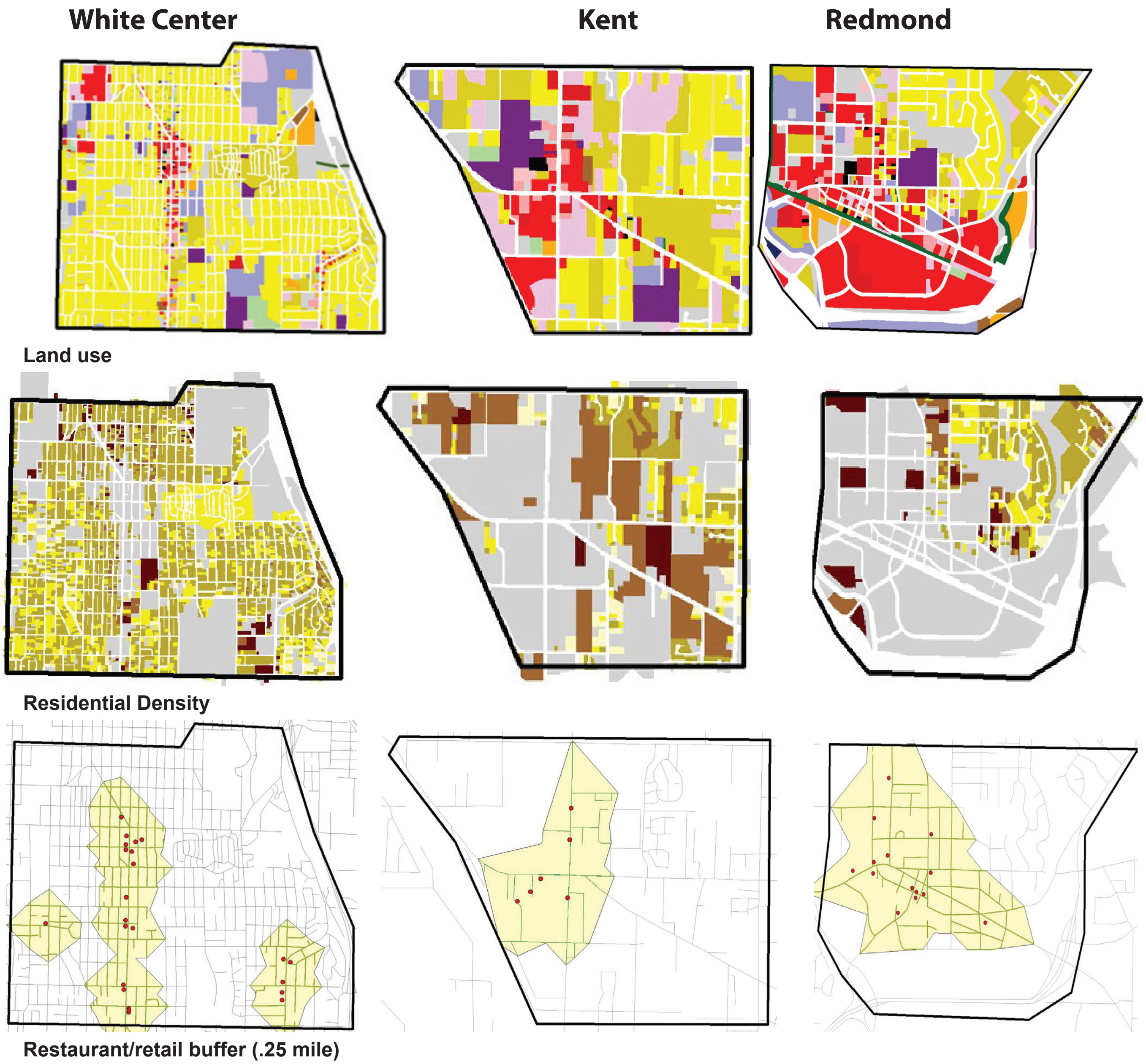



Figure 43: Comparison of Land Use Measures

## Travel Time to Key Destinations by Walking

The relative inaccessibility of commercial destinations revealed in the review of land uses above is confirmed by survey respondent reporting on destinations that are within a five minute walk of their homes. As shown in Table 77 below, the only destinations that are within a five-minute walk of at least 30 percent of homes in Kent East Hill and White Center were bus stops and convenience stores; in Redmond only bus stops and parks were within reach of 30 percent of homes in five minutes. Thirty percent of respondents in Kent East Hill and White Center could reach a slightly wider range of shops and services within a ten minute walk of home than that same percentage of Redmond respondents.

Greater differences arise when respondents reported those destinations that were more than a 30 minute walk from home. While more than 30 percent of respondents in all three communities reported that their jobs would be at least a 30 minute walk from home, the same percent of Kent East Hill and White Center respondents reported that a wide range of other shops and services were also more than a 30 minute walk from home.

| | Kent | Redmond | White Center |
|---|---|---|---|
| **Within 5 minutes of home for at least 30% of respondents** | Bus stop<br>Convenience store | Bus stop<br>Parks | Bus stop<br>Convenience stores |
| **Within 10 minutes of home for at least 30% of respondents** | Schools<br>Parks<br>Supermarket<br>Hardware store<br>Fruit/vegetable market<br>Laundry<br>Fast food<br>Coffee shop<br>Bank<br>Restaurant<br>Video store<br>Pharmacy | Schools<br>Convenience store<br>Supermarket<br>Laundry<br>Fast food<br>Coffee shop<br>Bank<br>Restaurant<br>Video store<br>Pharmacy | Schools<br>Parks<br>Supermarket<br>Laundry<br>Fast Food<br>Coffee shop<br>Bank<br>Restaurant<br>Video Store<br>Pharmacy<br>Salon<br>Park |
| **Greater than a 10 minute walk for at least 30 % of respondents** | Library<br>Gym<br>Job<br>Recreation Center<br>Liquor Store | Hardware store<br>Job | Clothing store<br>Post office<br>Library<br>Book store<br>Job<br>Doctor |

**Table 77: Accessibility of destinations to community residents**

## Urban Form

Each of the urban form measure maps in Figure 44 below show a 1km square area; each is focused on the commercial core of the case study site. The three rows of maps display block size, intersection density, and a figure-ground perspective of building area and open space.

The block diagram demonstrates the significant differences in block size, block layout and public street network pattern between the 3 case study communities. White Center has the block layout of a classic late 19th century/early 20th century 'streetcar' suburb; blocks are relatively small – 600 feet long by 270 wide – and streets are laid out in a grid pattern. Kent East Hill demonstrates the urban form typical of late 20th century suburban development: it is a formerly rural community that has been subdivided to accommodate 'suburban cluster' development. Kent East Hill has very large blocks – some as long as 2000 feet. The few public streets are laid out on a large grid, which tends to conform to the section and plat lines defined by the land ordinance survey. Within these large public blocks are autonomous systems of private streets within multifamily and single family developments. Redmond is a curious hybrid of early and late 20th century urban forms: it has an older core of small blocks on the same scale as White Center, created when Redmond first evolved as a community in the early 20th century. However, it also has large blocks, although not as large as in Kent, which are filled with late 20th century retail and commercial development.

The intersection density diagram reveals the different connectivity patterns in each community. White Center has high connectivity with its gridiron of intersections, whereas Kent East Hill demonstrates low connectivity due to its enormous distances between intersections. Redmond displays a medium connectivity rate: there are areas with higher connectivity due to smaller block sizes, but there are also areas within Redmond that have low connectivity due to the street network pattern of large blocks and dead end streets. Redmond's grid network, in essence, has gaps that are waiting to be filled in.

The figure/ground diagram illuminates the relationship between built form and open space. White Center, for the most part, displays what we would call a fine grained development pattern: small buildings, on small lots, with most buildings placed close to the street that help to define a closed-in form to the street. In the commercial core along 16$^{th}$ Avenue SW, buildings are located right on the property line, creating a coherent 'street wall' for two to three blocks and giving the strip a classic 'main street' feel. At the same time, there are significant 'holes' within the pattern of buildings in White Center, representing either vacant lots or open spaces, which break the continuity of urban form.

Kent East Hill displays a courser grain of commercial development; the retail buildings are very large and surrounded by the empty space of paved parking lots. The multifamily developments that surround Kent East Hill's shopping centers have a finer grain, being made up of small buildings often laid out on a grid pattern. However, the space between these buildings is private space, not public rights of way as in White Center.

Redmond contains a mixture of development patterns and grains, including large buildings and blocks of auto-oriented retail and commercial development, but also the finer grain of early 20$^{th}$ century 'downtown' and more recent infill of high density residential and mixed use development.


**Figure 44: Comparison of urban form measures**

## Main Street Section

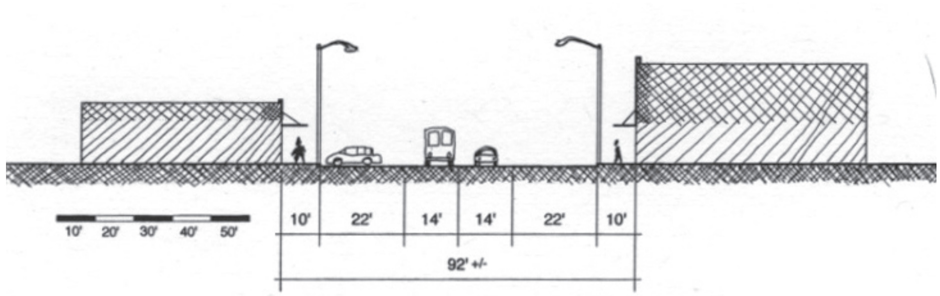
The 'Main Street' sections in Figure 45 below also demonstrate the significant differences in development patterns between the 3 case study areas. Cross sections are presented for one primary commercial street in each community. The street sections show the street width, the number, width and configuration of travel lanes, the presence or absence of parking, the distance between buildings and the street front, and the scale of pedestrians within these configurations. Cross sections are presented at the same scale for each community.

Sixteenth Avenue SW in White Center displays the classic form of an early 20th century main street: buildings are located on the property line, creating a distinct 'street wall' and a feeling of enclosure to the street. Sidewalks are narrow, but provide easy access for pedestrians. The diagonal parking provides a buffer between pedestrians on the sidewalk and the through traffic. It is a relatively wide right of way, but there are only two through travel lanes.

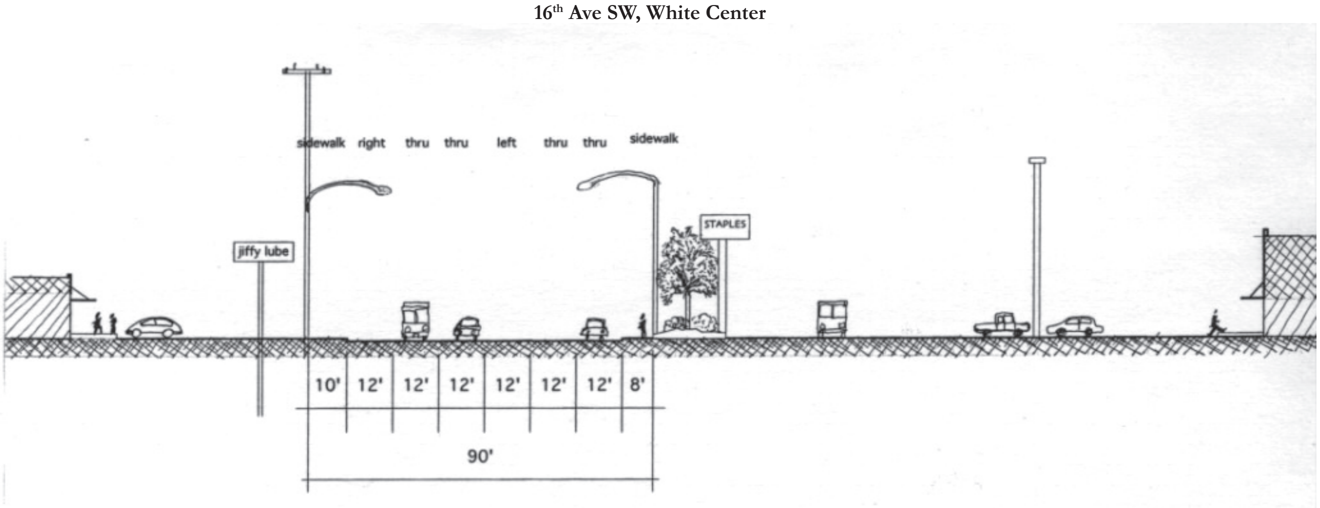
104$^{th}$ Avenue SE in Kent East Hill is also a wide street, about the same width as 16$^{th}$ Avenue in White Center; however, it appears considerably wider because the buildings are set so far back on the adjoining properties (and because the parcels and blocks are so big). The distance between the sidewalk and the building behind it is often as large or larger than the street width itself. This means that pedestrians have quite a distance to walk – usually through parking lots with no sidewalks or designated pedestrian path – in order to get to the front door of a building. This is typical of late 20$^{th}$ century development patterns that are essentially engineered to facilitate travel by automobile. Furthermore, the sidewalks are narrow and there is no buffer of parking, street trees or a planting strip to separate pedestrian sidewalks from through lane traffic.

Redmond Way also demonstrates late 20$^{th}$ century traffic engineering and development patterns, although the distance between the sidewalk and building entrances is not so large as in Kent due to smaller parcel sizes and a smaller scale of retail development. However, as in Kent, there is no buffer between the sidewalks and the roadway, although trees can be found in planting strips on some private properties. Parallel parking provides somewhat of a barrier for pedestrians on the south side of the street.

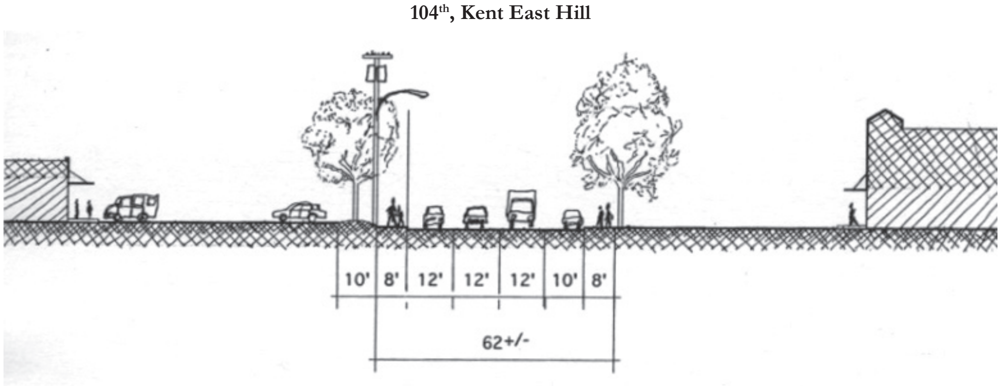
### Main Street Sections




16th Ave SW, White Center




104th, Kent East Hill




Redmond Way, Redmond

Figure 45: Comparison of Main Street Sections

## E. Comparison of Respondent Perceptions and Attitudes

In terms of community walkability, White Center respondents report themselves strongly dissatisfied with the condition of community sidewalks and safety from traffic, and are split on whether or not they feel safe from crime when walking. In addition, they provide somewhat ambiguous responses to questions about the availability of walking destinations in their community. While a majority state that they have shops, services and restaurants within walking distance, a majority also state that not having any place to walk to in their neighborhood is an important negative influence on their decision to walk. Despite these fairly negative responses to specific questions, a majority of respondents also report themselves moderately satisfied with the overall ease of walking in their community. These responses suggest that, while White Center respondents recognize the shortcomings of their community as a place to walk, they place relatively little importance on neighborhood walkability overall – a conclusion supported by their low ranking of community walkability as a consideration in their choice of home location.

Kent East Hill respondents reported that they were moderately satisfied with the condition of their sidewalks, but that they did not feel safe from traffic when walking. As with White Center, they reported on the one hand that they had restaurants, shops and services within walking distance of home, but that at the same time a lack of nearby destinations was an important negative influence on their decision to walk. Finally, as with White Center, a majority of respondents reported themselves moderately satisfied with community walkability, although they rated this concern very low in terms of its influence on their choice of home location.

Redmond respondents were most satisfied with current walking conditions in their community, with strong majorities reporting that their sidewalks were of high quality and that they felt safe from crime and traffic when walking. Also, the percentage of respondents who felt that the lack of places to walk to was an important negative influence on their decision to walk was smaller than in either of the other two communities, although a substantial number of respondents felt that steep hills were a constraint on walking. Finally, the percentage of respondents who ranked community walkability important as a consideration of home location was considerably higher than in the other two communities – 40 percent, compared to only 25 percent in both White Center and Kent East Hill.

As shown above in Table 77, a ten minute walking time appears to be an important threshold for access to a wide range of uses, such as restaurants, shops and services, in all three communities. Whether or not respondents see this as a reasonable walking distance is debatable, given their conflicting responses to questions about the accessibility of shops and services and the presence or absence of places to walk to near their homes. On the other hand, responses from all three communities accurately reflect the actual state of neighborhood sidewalks, and these answers correlate well with respondents' reported sense of safety from traffic: in Kent and White Center, where sidewalks are incomplete, respondents report feeling unsafe from traffic; in Redmond, where the sidewalk network is largely complete, respondents report feeling safe from traffic.

Finally, a majority of respondents in all three communities indicated that transit service and transportation costs were not important considerations in their selection of home location. More respondents reported themselves satisfied than dissatisfied with transit in all three communities, although large numbers of respondents also reported themselves neutral on the subject.

## F. Survey Respondent Travel Behavior

Travel survey respondents in the three communities completed a two-day trip diary where they reported the travel modes, purposes, and origins and destinations of each trip. The following descriptions highlight some of the stronger similarities and differences in travel behavior in the three communities.

### *How many trips do people make each day?*

Daily personal trip rates are quite comparable in the three communities, at 4.7 trips per day in Kent, 4.8 in Redmond, and 4.7 in White Center. SOV trip rates were highest in Redmond, transit trip rates were highest in White Center, and walking trip rates were highest in Kent East Hill. Trip rates break down by mode and community as shown in Table 78 below.

| | Kent | Redmond | White Center |
|---|---|---|---|
| SOV | 3.3 | 3.6 | 3.3 |
| Transit | 2.0 | 2.1 | 2.3 |
| Walking | 2.4 | 2.2 | 2.2 |

**Table 78: Trip rates by key modes**

### *What purposes are people making trips for?*

Trips are only a means to an end, and the vast majority of trips taken in the communities serve to meet everyday household needs. In all three communities, excluding return trips to home from a variety of destinations, the top four trip purposes were traveling to work, traveling to school, incidental shopping, and picking up and dropping off others. Further breakdowns by community are provided in Table 79 below.

| | Kent | White Center | Redmond |
|---|---|---|---|
| To work/work related | 41.0% | 40.5% | 41.5% |
| To school | 12.2% | 12.0% | 11.3% |
| Incidental shopping (errands) | 9.9% | 10.5% | 8.9% |
| Drop-off/pick-up | 6.0% | 5.9% | 6.9% |
| Eating out | 4.9% | 4.3% | 4.1% |
| Personal business | 4.8% | 3.6% | 4.5% |
| Entertainment | 2.8% | 2.5% | 2.2% |
| Other activity | 2.8% | 3.2% | 2.2% |
| Waiting for transportation/ Changing modes | 2.3% | 4.2% | 3.4% |
| Visiting friends and relatives | 1.8% | 2.4% | 2.5% |
| Fitness/exercise | 1.8% | 1.8% | 1.6% |
| Major shopping | 1.4% | 0.8% | 1.7% |
| Church activities | 1.1% | 1.1% | 1.7% |
| Medical/dental | 0.9% | 0.9% | 0.8% |
| Civic activities | 0.3% | 0.4% | 0.4% |
| Recreation | 0.3% | 0.7% | 0.1% |

**Table 79: Comparison of reported trip purposes by community**

### *On average, how long are trips for different purposes?*

Some daily needs can be met near the home; others require respondents to travel farther afield. Trip purposes that consistently require residents to travel far from home may indicate a deficiency in the range of shops, services and other destinations in the local community. Results for these and all following descriptions are presented in Table 80 at the end of this section of the chapter.

### *Shortest Average Trip Length by Purpose*

Respondents in all three communities consistently reported[7] that the shortest trips – those completed closest to home, likely within a few blocks – were for incidental shopping and travel to school. Other purposes, which were among the shortest trips made, were eating out and entertainment in Kent, eating out and going to church in Redmond, and civic and personal business in White Center.

### *Frequency of Purposes for Trips Under One Mile*

When trip purposes are examined according to their frequency by length, a slightly different pattern emerges: in all three communities travel to work is reported to be among the most frequent purpose for trips less than one mile in length. In Kent East Hill and Redmond, dropping off and picking people up also show up as frequent purposes for trips under one mile, and may correspond to adult household members taking children to school. In White Center and Redmond, changing modes/waiting for transportation was also frequently reported as a purpose of trips under one mile. All other purposes frequently reported at this length were the same as those for the shortest trips reported.

### *Longest Average Trips by Purpose*

In all three communities travel to work accounted for the third average longest trip length. In Kent East Hill and Redmond long trips were also reported for medical/dental and civic purposes. Other purposes that were associated with the longest trip lengths in the three communities were major shopping, recreation and entertainment, suggesting that respondents regularly access regional destinations outside their communities for these purposes. Generally speaking, the average lengths of trips for all purposes were shorter in Kent East Hill than in the other communities, suggesting that residents are able to meet more of their daily needs somewhat closer to home in this community, despite the fact that this community has the lowest street connectivity of all three case study locations.

### *Frequency of Purposes for Trips Over Five Miles*

Interestingly, three of the most frequently reported purposes for trips longer than five miles are the same as those for trips under one mile: getting to work, incidental shopping, and drop-offs and pick-ups. As shown in Table 79 above, with the exception of trips to school, these are also the most frequently reported trip purposes overall, suggesting that travel for these purposes is distributed among trips of all lengths.

7 While the trips themselves were reported by community residents, their actual length was calculated in a GIS environment.

Work trips are among the longest taken by residents in all three communities, yet, as previously noted, travel to work is also among the most frequent purpose of trips under one mile. Also, as will be described below, travel to work is one of the most frequently reported walking trip purposes. These results and the journey to work mode shares reported earlier in Table 66 and Table 67 suggest that, where work destinations are within a reasonable distance from home, a substantial portion of the population is willing to walk to accomplish the trip.

It is also worth noting that 65 to 70 percent of medical/dental trips reported by Kent East Hill and Redmond residents were found to be over five miles in length. This suggests that these communities may be under-serviced with medical/dental facilities, raising important accessibility concerns for elderly and lower income residents without regular access to private vehicles. In contrast, only 42 percent of medical/dental trips in White Center were longer than five miles; on the other hand, 73 percent of recreational trips in White Center were over five miles in length, suggesting a possible deficiency in open space in that community.

### *Which travel modes do people use to accomplish different trip purposes?*

Generally speaking, the trip diary results showed that transit, walking and driving are used to serve the same trip purposes but that walking is used to accomplish nearby purposes and transit more distant ones. Driving was used to accomplish trip purposes at all lengths. Details by community are presented below.

### *What is transit most frequently used for and long are the trips?*

Excluding changing modes, travel to work and school are among the most frequent purpose of transit trips in all three communities. In Kent East Hill and White Center, “other” is also a frequently reported purpose of transit trips, as is drop offs and pick ups in Redmond.

The focus of transit use on trips to work is not surprising, given that transit service is usually most efficient to destinations with large numbers of jobs, such as downtown cores. The fact that “other,” a category which comprises a wide variety of incidental trip purposes not captured in major categories, is such a significant focus of transit trips in Kent East Hill and White Center suggests that transit accommodates a wide range of travel needs in those communities. The significant use of transit for trips to school may reflect travel by bus by school age children. Drop off and pick up trips in Redmond may reflect the same underlying purpose.

By far the greatest majority of transit trips, at least 58 percent in all three communities, were over five miles in length, reflecting the fact that trips to work are also among the longest trips, on average, reported by community respondents. In Redmond, another 26 percent of transit trips were below one mile in length, a substantially higher proportion than was the case in either Kent East Hill or White

Center, implying that local transit service in Redmond is an effective means of accomplishing trip purposes close to home.

A question in the household survey asked respondents to rate how easy it was to access destinations in their communities by transit. Slightly more White Center respondents found that it was easy to reach work by transit than found it difficult. A large majority reported that it was easy to reach grocery stores and parks by transit, and a slight majority reported it difficult to access malls with this mode. Approximately 50 percent of Redmond survey respondents indicated that it was somewhat or very difficult to reach work or grocery stores by transit. There was no trend in terms of perceptions of the accessibility of parks or malls by transit in that community. Finally, responses by Kent East Hill residents indicate that, within that community, access to transit services, and the quality of those services, is unequal. For example, while approximately 60 percent of respondents indicated that it was very or somewhat easy to get to work by transit, another 25 percent indicated that it was very difficult to do so. Likewise, while one quarter indicated that it was very easy to reach malls by transit, another quarter indicated that it was hard. The majority of respondents from Kent East Hill reported that it was easy to access grocery stores and parks by transit.

### *What trip purposes do people walk for and how long are the trips?*

In all communities, excluding changing modes/waiting for transportation, travel to work and incidental shopping are the most frequently reported walking trip purposes, followed by eating out. Travel to school also ranked highly in Redmond and White Center, being the third and fourth most frequent walking trip purposes respectively, but only the seventh most frequent purpose in Kent. This may suggest that more children are being driven to school in Kent (reflected in its high frequency of drop off and pick up trip purposes for trips under one mile), or the school age population may be smaller in this community.

Not surprisingly, incidental shopping, eating out and travel to school were also the shortest trips reported by respondents, and travel to work was the most frequent purpose of trips under one mile. Clearly, respondents choose walking to accomplish short trips close to home. In Redmond and White Center 93 percent of walking trips were less than one mile in length. Interestingly, in Kent East Hill only 83 percent of walking trips were less than one mile in length. The fact that people are walking further in Kent East Hill supports the earlier finding that street connectivity was lowest in that community.

### *What sort of trip purposes are people driving for? How long are these trips?*

In all three communities the most frequent SOV trip purposes were the everyday tasks of traveling to work, incidental shopping, and picking up and dropping people off. Eating out and personal business were also frequent purposes. These generally also correspond to the most frequent overall trip purposes, as well as the most frequently reported walking trip purposes. The one exception is that driving is more frequently used to pick up and drop people off, and walking is more frequently used for travel to school.

In all three communities approximately 20 percent of SOV trips were less than one mile in length. In Redmond and White Center, and another 40 percent were over five miles, and in Kent East Hill 44 percent of SOV trips were over five miles in length.

### *On average, how far, and for how long, do people travel by car each day?*

Vehicle miles traveled have implications for both air quality and energy use, and trends in vehicle hours traveled provide us with information about congestion levels and their impact on quality of life. All three communities showed nearly identical outcomes on these two measures: respondents travel an average of 26.5 miles per day, and spend approximately 3.3 hours a day in vehicles. Kent East Hill residents spend slightly less – 3.1 hours per day – in vehicles, reflecting the shorter average trip lengths reported in this community. The Kent example clearly shows that having more destinations close to home has a direct relationship to spending less time in your car, even in a community where the street network displays low connectivity.

### *How do people get to work?*

One of the interesting findings of this research was the frequency with which people will walk to work when that destination is a reasonable distance from home. The case studies purposefully selected communities with residential neighborhoods near to commercial/office districts, and mode shares for the trip to work for these communities showed that 8 percent of work trips in Redmond and White Center and 11 percent of work trips in Kent East Hill were accomplished by walking. When only trips to work longer than one mile were considered, walking mode share dropped off to 1 percent in all three communities.

When trips to work of all lengths are considered, White Center had the highest carpool mode share at 17 percent and Redmond the highest SOV mode share at 73 percent. Transit mode shares ranged from 3 to 5 percent. Further details are presented in Table 80 below.

Finally, whereas 6 percent of those employed worked from home in Kent East Hill and White Center, twice that number, 12 percent, reported working from home in Redmond. There were no appreciable differences in work at home rates between men and women in any community.

| | Kent | Redmond | White Center |
|---|---|---|---|
| **Shortest Reported Trips, in order of frequency reported** | Entertainment<br>Eating out<br>Incidental shopping<br>To school | Church<br>To school<br>Eating out<br>Incidental Shopping | Civic<br>To school<br>Incidental shopping<br>Personal business |
| **Most Frequent Trips Under 1 Mile, in order reported** | Incidental shopping<br>To work<br>Pick up/drop off<br>Eating out | Incidental shopping<br>Pick up/drop off<br>To work<br>Eating out | Incidental shopping<br>To work<br>Eating out<br>Personal business |
| **Longest Reported Trips, by frequency reported** | Medical/dental<br>Civic<br>To work<br>Major shopping | Medical/dental<br>Civic<br>To work<br>Entertainment | Major shopping<br>Recreation<br>To work<br>Entertainment |
| **Most Frequent Trips Over 5 Miles, in order reported** | To work<br>Incidental shopping<br>Pick up/drop off | To work<br>Major shopping<br>Pick up/drop off | To work<br>Pick up/drop off<br>Incidental shopping |
| **Most Frequent Transit Trip Purposes, in order reported** | To work<br>Other<br>To school | To work<br>To school<br>Pick up/drop off | To work<br>To school<br>Other |
| **Percent of Transit Trips Over 5 miles** | 60% | 58% | 59% |
| **Most Frequent Walk Trip Purposes, in order reported** | To work<br>Incidental shopping<br>Eating out<br>Entertainment | To work<br>Incidental shopping<br>To school<br>Eating out | To work<br>Incidental shopping<br>Eating out<br>To school |
| **Percent of Walk Trips Under 1 Mile** | 83% | 93% | 93% |
| **Most Frequent SOV Trip Purposes, in order reported** | To work<br>Incidental shopping<br>Pick up/drop off<br>Eating out | To work<br>Incidental shopping<br>Pick up/drop off<br>Personal business | To work<br>Incidental shopping<br>Pick up/drop off<br>Personal business |
| **Percent of SOV Trips Under 1 Mile** | 20 % | 21% | 19% |
| **Percent of SOV Trips Over 5 Miles** | 44 % | 39% | 40% |
| **Average personal daily VMT** | 26.5 miles | 26.6 miles | 26.4 miles |
| **Average personal daily VHT** | 3.1 hours | 3.4 hours | 3.4 hours |
| **Mode Split for the Trip to Work (all trips)** | 70% SOV<br>14% HOV<br>11% Walking<br>4% Transit<br>1% Cycling<br>0% Other | 73% SOV<br>11% HOV<br>8% Walking<br>5% Transit<br>2% Cycling<br>0% Other | 71% SOV<br>17% HOV<br>8% Walking<br>3% Transit<br>1% Cycling<br>1% Other |
| **Mode Split for the Trip to Work (only trips longer than 1 mile)** | 77% SOV<br>16% HOV<br>5% Transit<br>1% Walking<br>1% Cycling<br>0% Other | 79% SOV<br>12% HOV<br>5% Transit<br>2% Walking<br>1% Cycling<br>2% Other | 77% SOV<br>18% HOV<br>3% Transit<br>1% Walking<br>1% Cycling<br>0% Other |

**Table 80: Summary of travel behavior in the three communities**

## IV. Recommended Urban Design Strategies

The intention of this section of the report is to articulate a range of land use, urban design, and transportation infrastructure strategies available to the case study communities. Strategies have been chosen that make sense for each case study site given their specific deficiencies and assets. The underlying goal behind these recommendations is the (re)development of an urban form that is more compact and better connected, so that walking, biking and the use of transit are increased and ultimately, regional air quality and public health are improved.

The previous section examined the urban design and land use contexts of each community to determine their assets and deficiencies and to target key urban form issues that need to be addressed. The case study team reviewed contemporary North American – and especially West Coast – urban design research, policy and practice for examples of transit oriented development and design and high density housing typologies that are both appropriate to the West Coast suburban context and complementary to existing plans and policies of the various jurisdictions in King County. The team examined public policies and investments as well as private development opportunities, and chose a variety of best practices and 'best typologies' as ways of illustrating a range of land use, transportation and urban design policies, strategies and investments which communities could pursue in order to shape a built environment more conducive to active living. These strategies are diagrammatic and conceptual, rather than "implementation ready."

The team has endeavored to identify land use and transportation investments that will serve not only land use targets and transportation capacity goals, but that will also help to improve public health, air quality, environmental sustainability, and civic accessibility, and, eventually, lead to the creation of a more coherent, livable, and aesthetically pleasing civic and public realm.

### *Summary of Urban Design Strategies*

All three case study locations have a diverse and concentrated mix of land uses; however, they all currently lack adequate residential density and pedestrian connectivity to generate high walking trip rates. Given these shortcomings, the team suggests three primary urban design and transportation strategies which are applicable to all three communities:

- ***Increasing residential density*** in commercial areas by allowing and promoting more mixed use and high density residential development.
- ***Creating a Greenways/public ways system*** which connects public spaces with a series of pedestrian and cycling routes at three levels: within each neighborhood, between neighborhoods within the community, and between communities via a series of regional trails.
- ***Introducing improvements to major community streets*** through streetscape improvements – including development of sidewalks – and street design changes which support their use by pedestrian and bicyclists.

Each of these strategies addresses multiple concerns and issues that were made evident in the analysis of existing conditions. Applications of the strategies to each community are outlined below and described in more detail in Appendix V, the Case Study Report.

## A. White Center

From the analysis of existing conditions, it is evident that White Center has a well-connected network of streets, but lacks the pedestrian features necessary to support walking. White Center also needs a greater concentration of people living within walking distance of its commercial areas.

White Center does not need to build in additional street network connectivity. Instead, it needs to add pedestrian amenities such as sidewalks, buffers, street trees, crosswalks, and pedestrian scaled street lights. In some locations traffic calming may also help make walking feel safer. White Center could also use an increase in retail and commercial destinations spread throughout the community in the form of nodes of retail shops, convenience stores, and restaurants, as most residents are currently too far from existing commercial areas to comfortably walk to them.

Specific strategies proposed for White Center include:

- Rezoning single family neighborhoods to allow infilling with duplexes and triplexes to increase residential density.
- The completion of the sidewalk and street drainage system, including design and development of natural drainage systems.
- Creation of an international marketplace/small business incubator building.
- Development of alternative affordable housing options.

Details on these strategies are provided in the full case study report.

### White Center Community Aspirations as Identified in Respondent Comments in the Surveys

Survey respondents were asked what kinds of land uses near to transit stations would encourage them to use transit more often, and more generally, their opinion of a series of potential public investments in the community. They were also surveyed for their preferences among pairs of land use and urban form measures and contrasting community styles. Responses to these questions are described below.

#### *Land Uses that Would Encourage Residents to use Transit More Often*

When asked what sorts of places near transit or rail stations would encourage them to use transit more often, White Center respondents indicated a grocery store most frequently, followed in descending order by a bank or credit union, a restaurant or tavern, a doctor or health clinic, and a park.

### *Opinions on Possible Public Investments in the Community*

The most frequent choices for top priority in community public investment were completing the sidewalk system, development of additional affordable housing, and more parks and open space. The top picks for second priority were more small businesses and services, completing the sidewalk system, and once again, affordable housing. Finally, the two choices which stood out as equally popular for third most important investment in White Center were improved residential street lighting and a pedestrian and bicycle trail system.

The potential investment perceived most undesirably by White Center respondents was new or expanded freeways, which 24 percent rated as extremely or somewhat undesirable. Nineteen percent felt the same way about public investment in a park and ride lot.

### *Preference for Community Level of Activity and Mix of Housing*

When asked if they would prefer to move to a neighborhood that was lively and active, even if it meant a mix of housing types on smaller lots, or in a neighborhood with single family homes on large lots, even if it meant that the neighborhood was not especially lively or active, White Center respondents showed a slight preference for the less active community with single family homes on large lots over the lively community with mixed housing on smaller lots. A small majority felt that White Center was currently more similar to the large lot – single family home choice, and a majority also indicated a preference for their current community over either choice.

### *Preference for Ability to Walk to Nearby Shops and Services in the Community*

When asked if they would prefer to move to a community where the shops and services are kept separate from homes, even if that would mean they could not walk to them, or to a community where shops and services are within walking distance, even if that meant they were within a few blocks of their homes, a majority of White Center respondents indicated a preference for the second scenario. A majority also felt that White Center is currently more like the second choice than the first, though a sizeable minority felt that it was like both choices. Finally, a majority again indicated that they would rather live in a community like their current one than either of the choices, though a fair minority showed a preference for one with increased ability to walk to shops and services.

### *Preference for street types and travel options in the community*

White Center respondents showed a strong preference for a neighborhood with through streets that allow walking, cycling and use of transit to accomplish trip goals over neighborhoods with cul-de-sacs that require driving for most trips. In addition, unlike Kent East Hill and Redmond, a large majority of White Center respondents indicated that their neighborhood was like the first option, with very few indicating that it resembled both or was like the second option. Finally, as with the other communities, a majority of White Center respondents indicated that if moving they would hope to find a community like their current one, though in this case the first option was also a strong second choice.

### *Overall Community Preference*

A final series of survey questions asked respondents to indicate their preferences between two neighborhoods that were distinguished along a number of dimensions, rather than by single characteristics as in the questions described above.

The first community was described as having a mix of housing types on small lots, shops and services within a few blocks of home, local destinations within walking or driving distance (though parking was limited at nearby destinations), nearby public transit, and a one-way commute to work of three miles.

The second community was described as being composed of single family homes on acre lots; shops and services were described as being a few miles away, meaning they were too far to walk to – though parking at these destinations was ample; public transit was described as distant; and the one-way commute to work was given as 18 miles. The survey asked respondents to assume that the neighborhoods were the same in all other respects.

Approximately 75 percent of respondents in White Center showed a preference for the first option. When asked to rate both options separately, responses broke down as shown in Table 81 below. Neutral rankings are not presented.

| | White Center | |
|---|---|---|
| | **Like** | **Dislike** |
| **Compact mixed use** | 49% | 29% |
| **Suburban discrete use** | 33% | 40% |

**Table 81: White Center Respondent Community Style Preferences**

## Correspondence of Community Aspirations with Recommended Strategies

In many ways the comments of respondents are strongly supportive of the strategies proposed for White Center. Respondents rate the improvement of sidewalks, the creation of affordable housing, and the development of small businesses as high priorities – all measures that are recommended for the community. Respondents also show a desire for more open space in the community, a development which, if pursued, could help to reduce trip lengths for recreational trip purposes. Finally, they are strongly supportive of mixed land uses, the availability of shops and services within walking distance of home, and gridiron street networks which decrease distance to destinations.

However, White Center respondents showed a strong preference of single family homes on large lots over compact developments which mix various housing types on smaller lots. This suggests that they will not be immediately receptive to proposals to in-fill residential areas with duplexes and triplexes.

Their objection is clearly focused on lot size, because in the final survey question, which asks them to make tradeoffs between a neighborhood with the combined features of mixed use and small lots that is walkable and one with discrete uses and large lots that is auto-dependent, they clearly prefer the former.

## B. Kent East Hill

Kent East Hill is a prototypical suburban cluster – it has a large concentration of strip mall and big box retail at its core, surrounded by high density multifamily housing projects. While it has a good mix of land uses, it is lacking in pedestrian connectivity. Its underlying structure is automobile oriented, and it will take some years to convert this into a pedestrian and transit oriented community.

In addition to the generally recommended strategies of developing greenways, increasing residential density in commercial areas, and improving street connectivity, a series of specific strategies have also been created for Kent East Hill by the case study team. These include:

- Developing a rapid bus station at the intersection of 104th Avenue and 256th Street with direct connections to the transit station in downtown Kent.
- Providing efficient connections to other modes from the Kent East Hill station by integrating cycling facilities, pedestrian routes, and local bus routes with the station, and developing a dedicated park and ride lot nearby.
- Creating a system of linear parks along unimproved rights of way to create a 'green ring' of public open space around Kent East Hill.
- Encouraging the gradual redevelopment of shopping malls and big box retail to mixed use development.
- Discouraging surface parking through design guidelines.
- Permitting and encouraging housing development above retail space.

Details are provided in the full case study report.

### Community Aspirations as Identified in Respondent Comments in the Surveys

#### *Land Uses that Would Encourage Residents to use Transit More Often*

When asked what sorts of shops or services located near a transit station would encourage them to use transit more often, the great majority of Kent East Hill respondents indicated a grocery store would be an important asset. Significant numbers also indicated that the presence of a bank or credit union, retail stores, a doctor or health clinic, and restaurants and taverns would also encourage them to use transit more often.

### *Opinions on Possible Public Investments in the Community*

A majority of Kent East Hill respondents indicated that they found a proposed series of public investments desirable, though for some proposals a large portion of the sample gave a neutral response. The investment most frequently picked as the top choice by Kent respondents was affordable housing, followed by a complete sidewalk system and new or expanded freeways. Affordable housing was again chosen most frequently as a second priority, followed by a network of pedestrian and bicycle pathways and new or expanded freeways. There was a more evenly distributed range of choices for the third priority public investment, with more parks and open space, a completed sidewalk system and improved street amenities such as benches and trees showing a slight advantage. The two proposed investments which gained the strongest disapproval ratings were a community center and new or expanded freeways, at 15 and 14 percent extremely or somewhat undesirable respectively.

### *Preferences for Level of Activity and Mix of Housing in the Community*

When asked if they would prefer to move to a neighborhood that was lively and active, even if it meant a mix of housing types on smaller lots, or in a neighborhood with single family homes on large lots, even if it meant that the neighborhood was not especially lively or active, a clear majority of Kent East Hill respondents indicated they would prefer the latter. Respondents were evenly split on whether their current community was more like the first or second choice, but a slight majority still indicated that they would prefer to find a neighborhood more like the second choice than Kent East Hill was now.

### *Preference for the Ability to Walk to Nearby Shops and Services*

When asked if they would prefer to move to a community where commercial areas are kept separate from homes, even if that would mean that shops and services were too far to walk to, or in a community where shops and services are within walking distance, even if that meant they were within a few blocks of their homes, a sizable majority of respondents from Kent East Hill chose the latter option. Most respondents also thought that Kent East Hill was currently like this second scenario, although a significant minority felt that it was equally like both options. Finally, in terms of the ability to walk to shops and services, Kent respondents showed a strong preference for a community like their present one, with the second option above a weak second choice.

### *Preference for Community Street Types and Travel Options*

When asked if they would prefer to live in a) a neighborhood with cul-de-sacs and few people from other neighborhoods walking or driving on them, even if it means having to drive for all their trips, or b) a neighborhood where they can walk, cycle or take transit for some trips, even if it has through streets and people from other neighborhoods walking or driving on them, a slight majority of Kent East Hill residents chose the first option. At the same time, a larger majority indicated they thought Kent East Hill was currently more like the second option, belying the case study findings that Kent East Hill has low street connectivity compared to the other case study locations. Interestingly, a majority of respondents indicated that if moving they would hope to find a neighborhood like their current one, though a sizeable minority indicated they would hope to find one like the first choice above.

### *Overall Community Preferences*

A final series of survey questions asked respondents to indicate their preferences between two neighborhoods that were distinguished along a number of dimensions, rather than by single characteristics as in the questions above.

The first community was described as having a mix of housing types on small lots, shops and services within a few blocks of home, local destinations within walking or driving distance (though parking was limited at nearby destinations), nearby public transit, and a one-way commute to work of three miles.

The second community was described as being composed of single family homes on acre lots; shops and services were described as being a few miles away, meaning they were too far to walk to – though parking at these destinations was ample; public transit was described as distant; and the one-way commute to work was given as 18 miles.

The survey asked respondents to assume that the neighborhoods were the same in all other respects.

Unlike White Center, only 54 percent of respondents from Kent East Hill showed a preference for the first option. When asked to rate both options separately, responses broke down as shown in Table 82 below. Neutral ratings are not presented.

| | Kent | |
|---|---|---|
| | **Like** | **Dislike** |
| **Compact mixed use** | 48% | 20% |
| **Suburban discrete use** | 51% | 25% |

**Table 82: Kent East Hill Respondent Community Style Preferences**

## Correspondence of Community Aspirations with Recommended Strategies

As with White Center, Kent East Hill respondents were strongly supportive of the creation of affordable housing, improvement and completion of the sidewalk system, and development of a system of greenways for walking and cycling. Respondents also showed a preference for the mixed use that ensures the presence of shops and services within walking distance of home.

As with White Center, respondents showed a preference for neighborhoods composed of single family homes on large lots over compact developments with a mix of housing types on smaller lots. However, unlike White Center respondents, in the forced trade off between two complete neighborhoods presented in the final survey question, Kent respondents were more evenly split in their preferences between the two choices, indicating that they weigh the value of large lots more highly than White Center respondents, relative to the benefits of mixed use and walkability.

In addition, unlike White Center, Kent respondents showed a preference for cul-de-sac street networks over gridiron networks – a preference that may not be compatible with their desire to have shops and services within walking distance of home. This preference may reflect a degree of community self-selection among Kent East Hill respondents; the community currently contains many private cul-de-sacs, and some respondents may have chosen to live there precisely because they prefer that development style. The preference may also reflect a lack of familiarity with alternative development styles. In either case, this result suggests that persuading Kent residents that their community would benefit from greater street connectivity will require their consideration of the tradeoffs between walkability and privacy.

Finally, Kent East Hill respondents showed strong support for expansion of the freeway system linking their community to Greater Seattle. Clearly, Kent residents value the regional mobility afforded by the automobile.

## C. Redmond

Redmond is a thriving community that has a lot of potential to become a vibrant and diverse city with a wealth of public amenities and recreational resources. Redmond's primary deficiency is its lack of residential density in the commercial core. This is beginning to be addressed, and a number of developments have been constructed in the past few years which are creating high density urban housing in the commercial core. Some of the projects that have been built have taken care to use New Urbanist design principles – Lion's Gate Housing is such an example.

In recognition that it is undergoing tremendous growth, Redmond has already developed a Transportation Plan for the downtown area. Its recommendations include:

- Completing the street grid throughout downtown
- Creating gateways and pedestrian/bike connections
- Improving the pedestrian environment
- Converting Redmond/Cleveland to two way circulation after the completion of Bear Creek Parkway

- Re-using the Burlington Northern Santa Fe Railroad right of way for transit, trails and open space.
- Developing connections between downtown and the new Redmond Town Center.

In addition, the City of Redmond is also working on a Downtown Element to its Comprehensive Plan Amendment. The Downtown Element emphasizes the goal of retaining Redmond's distinctive character through urban design, street design, and open space guidelines and regulations that reduce regulatory barriers to innovative housing forms such as cottage homes and duplexes. The plan's vision for downtown Redmond has been based on many years of workshops with people who live and work in Redmond. It seeks to create a city which is pedestrian and bicycle friendly, which provides attractive and safe places to live close to amenities, and which meets community needs for employment, shopping, recreation, civic activities, cultural and entertainment amenities (Redmond 2004). In short, Redmond is already taking many of the steps needed create a more walkable and livable environment. Nevertheless, in addition to its existing policies, the case study team also recommends the following strategies:

- Developing appropriate local models for high density urban housing.
- Permitting development of non-traditional housing forms, such as live-work spaces.
- Completing an internal bike path network.
- Re-developing an appropriate street hierarchy, in order to emphasize the local-serving nature of some streets

Details are provided in the full Case Study Report in Appendix V.

### Community Aspirations as Identified in Respondent Comments in the Surveys

#### *Land Uses that would Encourage Residents to use Transit More Often*

Redmond respondents indicated most frequently that the place near a rail or bus station which would encourage them to use transit more was a grocery store, followed by a restaurant or tavern, a retail store, a park and a bank or credit union.

#### *Opinions on Possible Public Investments in the Community*

As with Kent, all proposed investments were rated more desirable than undesirable, though many also had large neutral ratings. When asked to rank their top three, Redmond respondents selected affordable housing most frequently, followed by a new or expanded freeway, more open space, and a pedestrian and bicycle trail system. The most frequent selections for second place were a pedestrian and bicycle trail system, improvements to arterial roads, and affordable housing. Opinion was more divided on third choices, with the top three choices being more small businesses and services, more parks and open space, and, again, affordable housing.

The two proposals which garnered the largest undesirable ratings were new or expanded freeways at 19 percent, and park and ride lots at 13 percent.

### *Preference for Community Level of Activity and Mix of Housing*

When asked if they would prefer to move to a neighborhood that was lively and active, even if it meant a mix of housing types on smaller lots, or in a neighborhood with single family homes on large lots, even if it meant that the neighborhood was not especially lively or active, Redmond respondents, unlike those from Kent, were more evenly split in their preferences. They were again relatively evenly split on the question of whether their current community was more like the former or the latter choice. However, a large majority indicated that they would prefer to move to a community that was more like their own than like either of the two choices.

### *Preference for Ability to Walk to Nearby Shops and Services in the Community*

A strong majority of Redmond residents indicated that they would prefer to move to a community where shops and services are within walking distance, even if that meant they were within a few blocks of their homes, rather than a community where the shops and services are kept separate from homes, even if that would mean they couldn't walk to them. A slight majority also felt that Redmond was currently more like the former choice than the latter. Finally, most Redmond respondents indicated they would like to move to a community similar to their current one, the next most popular choice being the one with shops within walking distance.

### *Preference for Community Street Types and Travel Options*

When asked if they would prefer to live in a neighborhood with cul-de-sacs that required driving for all trips but had few non-neighbors walking or driving on them, or a neighborhood with through streets that allowed walking, biking and taking transit for some trips but had non-neighbors walking on them, a strong majority of Redmond residents chose the second option. The respondents were evenly split on whether Redmond is more like the first or second scenario, though a large majority indicated that if moving they would hope to find a community more like their current one than either option. The through street scenario was a weak second choice in this last question.

### *Overall Community Preference*

A final series of survey questions asked respondents to indicate their preferences between two neighborhoods that were distinguished along a number of dimensions, rather than by single characteristics as in the questions above.

The first community was described as having a mix of housing types on small lots, shops and services within a few blocks of home, local destinations within walking or driving distance (though parking was limited at nearby destinations), nearby public transit, and a one-way commute to work of three miles.

The second community was described as being composed of single family homes on acre lots; shops and services were described as being a few miles away, meaning they were too far to walk to – though parking at these destinations was ample; public transit was described as distant; and the one-way commute to work was given as 18 miles.

The survey asked respondents to assume that the neighborhoods were the same in all other respects.

Approximately 75 percent of respondents in Redmond showed a preference for the first option. When asked to rate both options separately, responses broke down as shown in Table 83 below. Neutral ratings are not presented.

| | Redmond | |
|---|---|---|
| | Like | Dislike |
| **Compact Mixed Use** | 54% | 30% |
| **Suburban Discrete Use** | 25% | 38% |

**Table 83: Redmond Respondent Community Style Preferences**

### Correspondence of Community Aspirations with Recommended Strategies

As in Kent and White Center, Redmond respondents were strongly supportive of the creation of affordable housing. They are also in favor of the development of a system of pedestrian and bicycle trails, the creation of more open space, and the development of more small businesses. On the other hand, respondents are also in favor of the expansion of the regional freeway system and improvements to local arterials, indicating that while they favor the development of more walkable local neighborhoods, they also want to maintain or improve levels of regional access by automobile.

Redmond respondents showed a clear preference for a gridiron street network and a mix of housing and other uses so that shops, services and restaurants are accessible on foot. Redmond respondents were more evenly split in their preference for single family homes on large lots versus compact development with a mix of housing styles on smaller lots when compared to the other two communities. However, in the final forced choice question respondents showed a strong preference for the compact mixed use community over the suburban discrete use community. These responses suggest that, more than in Kent or White Center, Redmond respondents will be amenable to the development of higher density, mixed use neighborhoods featuring a range of housing forms.

## V. Case Study Summary

The primary deficiencies identified in the three communities were a lack of mixing of residential and commercial uses, poor street connectivity, and incomplete or inadequate sidewalk systems. As reported in Chapter Four, all of these shortcomings decrease the walkability of the three neighborhoods for area residents. It is important to note, however, that respondents placed relatively little importance on community walkability, the quality of the transit system, or overall transportation costs when deciding where to live; walkability and access to alternatives to the automobile are secondary to respondent concerns such as housing affordability, quick access to work by car, and safety from crime. Nonetheless, it is likely that correcting the deficiencies outlined here would lead to increase rates of walking, and thus higher levels of physical activity, in the three communities.

The main strategies recommended for urban redesign in the three communities were developing networks of pedestrian and cyclist greenways, implementing street improvements such as completing the sidewalk network, increasing the mix of land uses, and increasing residential density in commercial areas. Respondents were strongly supportive of the concept of greenways, improvements to sidewalks, and increasing the mix of land uses to enable walking to shops and services from home. However, in the case of White Center and Kent East Hill especially, there was resistance to increases in density if that means smaller lots with a mix of housing types. Put bluntly, in addition to wanting to be able to walk to shops and services from home, respondents would also like to live on large lots in single family homes – two preferences which may not be compatible.

Chapter Six will briefly describe respondent usage and attitudes towards transportation demand management programs, and Chapter Seven presents an application of the research results at the county level.

# Chapter VI: Community Attitudes Towards TDM Programs & Mode Choice for the Trip to Work

## I. Overview

The Individual Questionnaire presented to Case Study community respondents asked a series of questions about their trip to work, as well as their usage of and attitudes toward transportation demand management (TDM) programs. Please see Appendix II for a copy of the questionnaire. Responses are presented below.

## II. Influences on the Choice of Mode to Work

As shown in Table 84 below, respondents in all three communities ranked vehicle availability and travel time as their top two considerations in mode choice for the trip to work. The ability to run errands was the third most important factor for Kent and Redmond residents, and the fourth most important for White Center residents.[1]

| | Kent | White Center | Redmond |
|---|---|---|---|
| **Vehicle Availability** | 1 | 1 | 1 |
| **Travel time** | 2 | 2 | 2 |
| **Errands** | 3 | 4 | 3 |
| **Travel Cost** | 4 | 3 | 6 |
| **Parking Availability** | 5 | 3 | 4 |
| **Parking Cost** | 6 | 4 | 7 |
| **Parking Location** | 6 | 5 | 5 |
| **Traffic Report** | 7 | 7 | 9 |
| **Sidewalks** | 8 | 6 | 8 |
| **Bike Lanes** | 9 | 8 | 9 |

**Table 84: Respondent ranking of the influence of various factors on their choice of mode to work**

An interesting difference between the three communities shows over the importance of travel costs. While this factor is rated the third and forth most important consideration by White Center and Kent respondents respectively, it is only the sixth most important consideration for Redmond respondents. Similarly, while parking costs are the fourth most important consideration for White Center respondents, they are only rank seventh in the order of Redmond commuters' concerns. These differences likely reflect the higher median household incomes found in Redmond.

1 Rankings are based on responses to a series of survey questions which asked respondents to rate the importance of these factors from 1 to 5, where 1 is unimportant and 5 is very important. The percent of respondents choosing 4 and 5 were combined to produce the order reported in Table 84.

## A. Employer-Provided Incentives for use of Alternatives to Driving Alone for the Trip to Work

Forty percent of Kent East Hill respondents indicated that their employers provide incentives for their employees not to drive alone to work. This figure rises to 46 percent of employers of White Center commuters, and 50 percent of employers of Redmond commuters. The most frequently provided incentives are flexible working schedules, followed by free or subsidized transit passes and bike lockers and storage.

### 1. Respondent Reported Frequency of use of Incentives

Figure 46 below displays the average weekly usage of employer-provided incentives. The figure shows that flexible work scheduling and free or subsidized transit passes were far and away the most frequently used incentives. In Kent and Redmond flexible scheduling were most frequently used, whereas in White Center free or subsidized passes were most frequently used. Only respondents who reported usage are included in this calculation of mean usage.

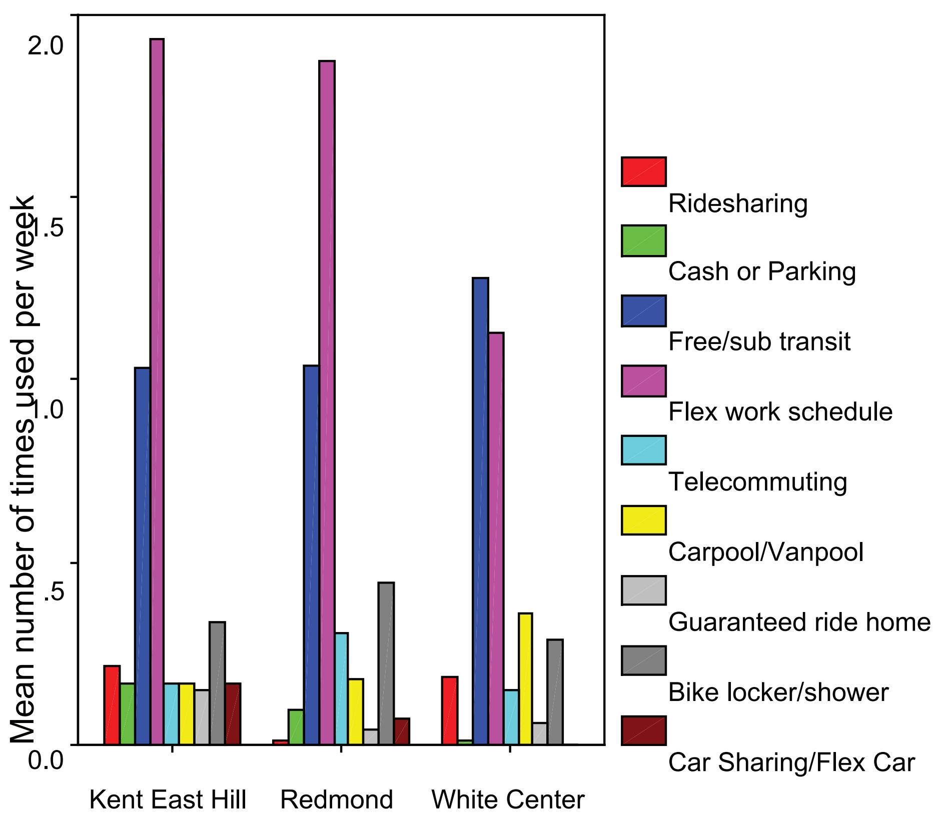



**Figure 46: Respondent reported frequency of use of TDM programs, by community**

Bike lockers and showers and in the case of White Center, carpool/vanpool programs were the next most frequently used incentives. Other employer-provided incentives show more variable usage rates by community. For instance, whereas in Kent and White Center use of ridesharing programs is relatively frequent, their usage is quite rare in Redmond. Conversely, while Kent and Redmond commuters make use of cash-in-lieu of parking programs and FlexCar services, such usage is rare to non-existent among White Center respondents. Finally, telecommuting is most frequent among Redmond respondents, and carpooling/vanpooling among White Center respondents.

## 2. Respondent Willingness to Consider use of Incentives if Offered in the Future

Generally speaking, respondents who currently do not have programs available showed low levels of interest in using TDM incentives if they were provided by their employers in the future. The only program which more than 25 percent of respondents in all communities indicated they would use was flexible work scheduling. In addition, 32 and 27 percent of Kent and Redmond respondents indicated that they would telecommute if the service was provided, but only 17 percent of White Center respondents indicated they would do so. Generally speaking, Kent East Hill respondents showed more interest in using the entire range of incentives than either Redmond or White Center respondents.

These results do not necessarily imply a lack of enthusiasm for use of these incentives. For example, it is possible that the provision of some incentives, such as free or subsidized transit passes, may already be widespread, and that further uptake will be limited. In addition, it is likely that projected levels of future use reflect respondents' own evaluation of the feasibility of making use of these incentives in their particular employment situations; for example, a respondent working for a small employer and living some distance from other workers might indicate that they wouldn't use carpooling/vanpooling because it would increase their travel time.

It is also possible that a lack of familiarity with employer-provided incentive programs also plays a role in respondent willingness to make use of such programs in the future. In all three communities a slight to moderate majority of respondents indicated that they would not know how to use such programs if they were available. Lack of familiarity was highest in White Center, with between 61 and 66 percent of respondents indicating they were unfamiliar with each incentive, and lowest in Kent East Hill, where between 51 to 60 percent of respondents indicated they did not know how to use each incentive.[2]

In any case, it is likely that, for Kent and Redmond respondents at least, the incentive program with the greatest "latent demand" is likely telecommuting. Twelve and 20 percent of Kent and Redmond respondents respectively indicate that their employer currently provide this program, while 32 and 27 percent respectively indicate they would use make use of it if it was provided in the future.

2 The Individual Questionnaire, included in Appendix II, provided respondents with a brief description of each TDM incentive program to accompany this series of questions.

### 3. Respondent Willingness to Consider Transit and Carpooling for the Trip to Work

When asked if they would take transit to work to save the money they currently spend on driving to work, more than 97 percent of respondents in all three communities answered no. In a follow up question asking how much additional money they would need to save to entice them to take transit, 75 percent of Kent, 60 percent of Redmond and 53 percent of White Center respondents indicated no amount would tempt them to switch modes. Small percentages – 11 percent in Kent, 14 percent in Redmond and 15 percent in White Center – indicated that a $25 per week savings would entice them to take transit to work.

Similar responses were reported to a series of questions which asked if respondents would be willing to carpool to save money. Ninety-seven percent of respondents in all three communities reported that they would not carpool to work to save the money they currently spend driving their car. When asked how much more they would need to save to be convinced to switch, 68 percent in both White Center and Redmond, and 73 percent in Kent East Hill said no amount of money would be sufficient. These results clearly show that a large majority of respondents are not willing to give up driving a car to work, even if such a decision would result in fairly substantial weekly savings.

An interesting contradiction appears when these results are compared to those described in Table 84. That table shows that travel costs are only the sixth most important consideration in mode choice for the trip to work among Redmond respondents, but the fourth most important consideration among Kent respondents. Nonetheless, more Redmond respondents reported themselves willing to consider switching to transit to save money. Clearly, the decision to switch modes involves more than simple financial considerations. Responses to a question which asked respondents what single factor would most influence their decision to use transit to travel to work are shown below in Table 85.

| | Kent | Redmond | White Center |
|---|---|---|---|
| Money savings | | 18% | 23% |
| Owning one less vehicle | 8% | 3% | 3% |
| Convenience of pick up/drop off locations | | 29% | 20% |
| Ability to read, work, or sleep during commute | 5% | 10% | 9% |
| Environmental concerns such as air pollution | | 21% | 9% |
| Other considerations | | 19% | 36% |

**Table 85: Factors which would most influence respondent decisions to take transit to work**

While convenience of pick up and drop off locations was the single most important factor for Kent and Redmond respondents (discounting the category other), money savings were the most important consideration among White Center respondents. Interestingly, environmental concerns were the second most frequently reported primary consideration among Kent and Redmond respondents, but were tied for third most frequent choice among White Center respondents, along with reading, working or sleeping during the commute.[3]

Finally, responses to a question which asked how much time respondents would be willing to spend travelling by transit to work, "assuming your ideal cost savings," are shown in Table 86 below.

| | Kent | Redmond | White Center |
|---|---|---|---|
| Will only spend less time than current commute | 17% | 10% | 11% |
| Willing to spend time equal to current commute | 60% | 69% | 63% |
| Willing to spend longer time than current commute | 23% | 21% | 26% |

**Table 86: Time willing to spend on transit, given cost savings, relative to current commute**

Kent respondents were most likely to indicate they were only willing to take transit if it took them less time than their current commute. White Center respondents were most willing to spend more time on transit then they spend in their current commute.

3 The category "other" included numerous respondent-specific concerns, such as "if I didn't have to carry large parcels to work," and "I work graveyards and don't feel safe on the bus."

# Concluding Remarks

The LUTAQH study is an unusually comprehensive interdisciplinary effort. It took five years to complete and had many important contributors. It is likely the only effort to date to integrate policy and basic research over land use actions, transportation investments, and their impacts on travel choice, air quality, climate change, and health related outcomes.

LUTAQH included an extensive outreach and research effort. On the research side it included the usage of both existing regional travel and parcel level land use data, as well as a household level survey within three communities of King County (White Center, Redmond, and Kent East Hill). Recommendations are drawn from the research that is applicable on a countywide level. Recommendations are also developed for these three communities which draw upon both the regional as well as the community specific research. LUTAQH builds upon the Atlanta based SMARTRAQ study, but offers some different lessons learned. Foremost is the need to understand the preferences of residents of specific communities and the unique history, travel, and behavioral characteristics and perceptions that create the identity of a place.

During the LUTAQH effort, King County took several steps to begin to improve coordination between transportation, health, and land use planning and policy. The next phase of LUTAQH will take the results from this effort and develop tools that can be applied to measure travel choices, and environmental and health related outcomes of land use and transportation investment decisions within King County. This next phase provides the capacity to make this work applicable within specific contexts and provide the critical link that is needed to apply the research to practice. LUTAQH has successfully built important partnerships and has established the makings of an extremely broad network of policies for achieving sustainability through healthy community design.

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