**INCORPORATE TRAVEL MODE CHOICES IN THE REGIONAL STRATEGIC PLANNING**

**MODEL (RSPM) TOOL**

**SPR 788**

By

Liming Wang

Jacqueline Nayame

Portland state University

Toulan School of Urban Studies and Planning

for

oregon department of transportation

Research Section

555 13th Street NE, Suite 1

Salem OR 97301

and

Federal Highway Administration

400 Seventh Street, SW

Washington, DC 20590-0003

**November, 2015**

Technical Report Documentation Page

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 1. 1. Report No. | 2. Government Accession No. | | | 3. Recipient’s Catalog No. | |
| 4. Title and Subtitle | | | | 1. Report Date   -month- -year- | |
| 1. Performing Organization Code | |
| 7. Author(s) | | | | 8. Performing Organization Report No. | |
| 9. Performing Organization Name and Address  Oregon Department of Transportation  Research Section  555 13th Street NE, Suite 1  Salem, OR 97301 | | | | 10. Work Unit No. (trais) | |
| 1. Contract or Grant No. | |
| 1. Sponsoring Agency Name and Address   Oregon Dept. of Transportation  Research Section and Federal Highway Admin.  555 13th Street NE, Suite 1 400 Seventh Street, SW  Salem, OR 97301 Washington, DC 20590-0003 | | | | 1. Type of Report and Period Covered   \_\_\_\_\_\_\_ Report | |
| 1. Sponsoring Agency Code | |
| 1. Supplementary Notes | | | | | |
| 1. Abstract | | | | | |
| 17. Key Words | | 18. Distribution Statement  Copies available from NTIS, and online at <http://www.oregon.gov/ODOT/TD/TP_RES/> | | | |
| 19. Security Classification (of this report)  Unclassified | 1. Security Classification (of this page)   Unclassified | | 21. No. of Pages  XXX | | 22. Price |

Technical Report Form dot f 1700.7 (8-72) Reproduction of completed page authorized Printed on recycled paper

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **SI\* (MODERN METRIC) CONVERSION FACTORS** | | | | | | | | | | | | | | | | |
| **APPROXIMATE CONVERSIONS TO SI UNITS** | | | | | | | | **APPROXIMATE CONVERSIONS FROM SI UNITS** | | | | | | | | |
| Symbol | | When You Know | Multiply By | | To Find | Symbol | | Symbol | | When You Know | Multiply By | | To Find | Symbol | | |
| **LENGTH** | | | | | | | | **LENGTH** | | | | | | | | |
| in | inches | | | 25.4 | millimeters | | mm | mm | millimeters | | | 0.039 | inches | | in | |
| ft | feet | | | 0.305 | meters | | m | m | meters | | | 3.28 | feet | | ft | |
| yd | yards | | | 0.914 | meters | | m | m | meters | | | 1.09 | yards | | yd | |
| mi | miles | | | 1.61 | kilometers | | km | km | kilometers | | | 0.621 | miles | | mi | |
| **AREA** | | | | | | | | **AREA** | | | | | | | | |
| in2 | square inches | | | 645.2 | millimeters squared | | mm2 | mm2 | millimeters squared | | | 0.0016 | square inches | | in2 | |
| ft2 | square feet | | | 0.093 | meters squared | | m2 | m2 | meters squared | | | 10.764 | square feet | | ft2 | |
| yd2 | square yards | | | 0.836 | meters squared | | m2 | m2 | meters squared | | | 1.196 | square yards | | yd2 | |
| ac | acres | | | 0.405 | hectares | | ha | ha | hectares | | | 2.47 | acres | | ac | |
| mi2 | square miles | | | 2.59 | kilometers squared | | km2 | km2 | kilometers squared | | | 0.386 | square miles | | mi2 | |
| **VOLUME** | | | | | | | | **VOLUME** | | | | | | | | |
| fl oz | fluid ounces | | | 29.57 | milliliters | | ml | ml | milliliters | | | 0.034 | fluid ounces | | fl oz | |
| gal | gallons | | | 3.785 | liters | | L | L | liters | | | 0.264 | gallons | | gal | |
| ft3 | cubic feet | | | 0.028 | meters cubed | | m3 | m3 | meters cubed | | | 35.315 | cubic feet | | ft3 | |
| yd3 | cubic yards | | | 0.765 | meters cubed | | m3 | m3 | meters cubed | | | 1.308 | cubic yards | | yd3 | |
| NOTE: Volumes greater than 1000 L shall be shown in m3. | | | | | | | |  |  | | |  |  | |  | |
| **MASS** | | | | | | | | **MASS** | | | | | | | | |
| oz | ounces | | | 28.35 | grams | | g | g | grams | | | 0.035 | ounces | | | oz |
| lb | pounds | | | 0.454 | kilograms | | kg | kg | kilograms | | | 2.205 | pounds | | | lb |
| T | short tons (2000 lb) | | | 0.907 | megagrams | | Mg | Mg | megagrams | | | 1.102 | short tons (2000 lb) | | | T |
| **TEMPERATURE (exact)** | | | | | | | | **TEMPERATURE (exact)** | | | | | | | | |
| °F | Fahrenheit | | | (F-32)/1.8 | Celsius | | °C | °C | Celsius | | | 1.8C+32 | Fahrenheit | | °F | |
| \*SI is the symbol for the International System of Measurement | | | | | | | | | | | | | | | | |

acknowledgements

Disclaimer

This document is disseminated under the sponsorship of the Oregon Department of Transportation and the United States Department of Transportation in the interest of information exchange. The State of Oregon and the United States Government assume no liability of its contents or use thereof.

The contents of this report reflect the view of the authors who are solely responsible for the facts and accuracy of the material presented. The contents do not necessarily reflect the official views of the Oregon Department of Transportation or the United States Department of Transportation.

The State of Oregon and the United States Government do not endorse products of manufacturers. Trademarks or manufacturers’ names appear herein only because they are considered essential to the object of this document.

This report does not constitute a standard, specification, or regulation.

**Table of Contents**

[1 LITERATURE REVIEW AND DATA EXPLORATION 2](#_Toc469949301)

[1.1 Socio-demographics 2](#_Toc469949302)

[1.2 Built Environment Variables 2](#_Toc469949303)

[1.3 Trip Context Variables 3](#_Toc469949304)

[1.4 Transportation Supply and Services 4](#_Toc469949305)

[1.5 Model Form of Mode Choice Models 5](#_Toc469949306)

[1.6 Travel Budget 6](#_Toc469949307)

[1.6.1 Household Travel Time Budget 6](#_Toc469949308)

[1.6.2 Household Monetary Budget 7](#_Toc469949309)

[1.7 Empirical Models 7](#_Toc469949310)

[1.7.1 GreenSTEP Model 7](#_Toc469949311)

[1.7.2 SmartGAP and EERPAT 8](#_Toc469949312)

[1.7.3 SILO Model 9](#_Toc469949313)

[1.7.4 IRPUD Model 9](#_Toc469949314)

[1.7.5 Impact 2050 11](#_Toc469949315)

[1.8 Data Sources 11](#_Toc469949316)

[1.8.1 National Household Travel Survey (NHTS) 12](#_Toc469949317)

[1.8.2 Regional Household Travel Surveys 12](#_Toc469949318)

[1.8.3 Smart Location Database 12](#_Toc469949319)

[1.8.4 Consumer Expenditure Survey 13](#_Toc469949320)

[1.8.5 Additional Datasets 13](#_Toc469949321)

[1.9 Conclusion 13](#_Toc469949322)

[2 REFERENCES 15](#_Toc469949323)

**LIST OF TABLES**

[**Table 1.1: Summary of factors identified in the literature** 8](#_Toc436425044)

[**Table 1.2: Model Form of Mode Choice Models** 10](#_Toc436425045)

# REVIEW OF LITERATURE AND DATA SOURCES

The purpose of this chapter is to review key drivers of mode choice behavior at household and individual level and to develop a mode choice module that incorporates some of most relevant factors. In the literature, those factors largely follow into four categories, namely, socio-demographic characteristics, built environment variables, trip context attributes, and measures of transportation supply and services. Table 1 summarizes the factors found in the literature reviewed.

## Key Drivers

### Socio-demographics

There are a number of socio-demographic characteristics influencing an individual’s choice of mode of transportation. According to Plaut (2005) there is a difference in preference or behavior in choosing non-motorized commute modes between renters and house owners, with a higher probability of renters switching from motorized to non-motorized. Income is a key variable in travel mode choice: Individuals and households with low income tend to have a high probability of walking and bicycling (Cervero and Duncan, 2003; Plaut, 2005). Research suggests that minority population are more likely to walk, with African Americans showing a higher probability of walking (Cervero, 1996; Cervero and Duncan, 2003). The presence of one or more children is associated with reduced likelihood of using non-auto mode choice (Cervero and Kockelman, 1997; Hamre and Buehler, 2014), which may be because households with children may have more rigid time budgets related to childcare and school schedules that lead to more complex trip-chaining as well as other factors. Gender plays an important role in the choice of non-motorized modes, with men more likely to use non-motorized travel modes compared to women (Cervero and Kockelman, 1997; Hamre and Buehler, 2014; Plaut, 2005; Schwanen and Mokhtarian, 2005a). Persons younger than 35 years are more likely to participate in active transportation compared to older age groups (Cervero and Duncan, 2003; Cervero and Kockelman, 1997; Hamre and Buehler, 2014; Plaut, 2005; Schwanen and Mokhtarian, 2005a), and the likelihood of using non-motorized transportation decreases with increasing age (Whitfield et al., 2015a). Access to car reduces the probability of an individual choosing a non-auto mode and increases that of driving (Cervero and Kockelman, 1997; Hamre and Buehler, 2014; Schwanen and Mokhtarian, 2005a).

### Built Environment Variables

Cervero and Kockelman (1997) summarize the built environment factors influencing travel behavior as 3Ds: density, design, and diversity. Later research gradually expands the factors into 5Ds: density, design, diversity, destination accessibility, and distance to transit (Ewing and Cervero, 2010, 2001). Past research has shown that density, pedestrian oriented design, and land-use diversity have an influence on an individual’s decision to use non-motorized mode of travel. Population density has an influence on an individual’s mode choice behavior: People who live in high-density areas are more likely to choose non-motorized modes than people who live in low-density areas. The design of built environments in a neighborhood has an influence on whether an individual chooses non-auto modes. The type of intersection influences on whether individuals choose to use auto or non-auto mode of transportation: neighborhoods with a high share of four-way intersections and limited on-street parking tend to average less single-occupancy-vehicle travel for non-work trips (Cervero and Duncan, 2003; Cervero and Kockelman, 1997; Schwanen and Mokhtarian, 2005a). Research by Cervero and Duncan (2003) reveals that areas with large city blocks and neighborhoods with large shares of 3-way intersections are not pedestrian/bicycle friendly environments. On the other hand, areas with 4-way intersections as well as intersections with 5 or more converging streets are shown to be pedestrian/bicycle friendly. Neighborhoods with grid pattern streets and few barriers between origin and destination pairs encourage commuting through walking and cycling.

Mixed use land-uses encourages non-auto commuting, having retail activities and consumer services within 300 feet of one’s residence have been found to encourage commuting by non-auto modes (Cervero, 1996; Cervero and Kockelman, 1997). Automobile usage is lower in higher density, more mixed use and pedestrian-friendly neighborhoods with a higher share of public transit and slow modes of transportation. The presence of mixed uses of land improves street connectivity, and higher densities appear to support non-motorized modes of travel.

Research by Schwanen and Mokhtarian (2005) compares how commuting mode choice differs by a residential neighborhood and by neighborhood type dissonance (a mismatch between a commuter’s current neighborhood and her preferences regarding physical attributes of the residential neighborhood). The level of residential type mismatch increases the probability of commuting by automobile. They found that mismatched urban residents were more likely to use automobile than mismatched suburban residents due to limited transit service. Mode choice differs according to a commuter’s residential neighborhood. Residential self-selection process has been found to play a significant role in explaining travel pattern behavior of individuals. Residents in the suburb have a higher probability of automobile use, while residents in urban areas show a higher probability of non-auto modes.

### Trip Context Variables

Trip context variables – variables directly related to the attributes of a trip, such as trip purpose, trip distance, time of the trip, safety and security, influence traveler’s mode choice decision. Trip purposes that do not require punctuality, such as travel to social and recreation/entertainment activities, have a higher probability of choosing walking. For different trip purposes, built environment factors have different influences on an individual’s mode choice decision.

Distance is an important factor in mode choice behavior. An increase in travel distance means an increase in travel time and effort needed for traveling, which leads to a reduction in commuters using non-auto modes (walking and cycling). The resistance to travel probably may increase disproportionately with distance due to the physical effort required (Heinen et al., 2010). Depending on the distance that a commuter has to travel, he/she will probably have to combine two different modes of travel or make transfers for non-driving modes. The extra effort required to make transfers has been considered to be a significant contributor to transit users’ inconvenience. Besides distance, other barriers to walking and cycling include steep slopes, nightfall and less secure environments (Heinen et al., 2010). Singleton and Wang (2014) document the effects of time of travel and safety and security concerns on the decision between driving and non-driving modes, especially for non-motorized modes.

### Transportation Supply and Services

The provision and level of service of a transportation mode have large impacts on the decision of choosing the mode. There is some overlap between built environment variables, trip context variables and variables measuring transportation supply and services, for example, distance to transit stops (a built environment variable) and transit services (a transportation supply and services variable). But in general, the former describes the built environment of the origin and/or destination or their relation to the transportation supply or services (e.g., distance to transit stops in this case), while the latter measures the presence and quality of transportation supply and services at the origin and destination and/or those connecting the two (e.g., the travel time by transit, the frequency or headway of transit system connecting origin and destination).

Research has found that availability and prices of parking (if not free) at the destination are influential factors in choices between driving and non-driving modes (Hamre and Buehler, 2014; Hess, 2001). Availability of bike parking and other facilities influences commuter’s choice of biking (Hamre and Buehler, 2014).

**Table 1.1: Summary of factors identified in the literature**

|  |  |
| --- | --- |
| **Variable** | **References** |
| **Social-demographic Characteristics** | |
| Age | (Cervero and Duncan, 2003; CERVERO and KOCKELMAN, 1997; Hamre and Buehler, 2014; MMWR, 2015; Plaut, 2005; Schwanen and Mokhtarian, 2005) |
| Gender | (CERVERO and KOCKELMAN 1997; Plaut 2005; MMWR 2015; Schwanen and Mokhtarian 2005; MMWR 2015; Hamre and Buehler 2014) |
| Income | (CERVERO and KOCKELMAN 1997; Cervero and Duncan 2003; Plaut 2005; Schwanen and Mokhtarian 2005; MMWR 2015; Hamre and Buehler 2014)  (CERVERO and KOCKELMAN 1997; Cervero and Duncan 2003; Hamre and Buehler 2014; MMWR 2015) |
| Race and Ethnicity | (CERVERO and KOCKELMAN 1997; Schwanen and Mokhtarian 2005; MMWR 2015; Hamre and Buehler 2014) |
| Household size | (CERVERO and KOCKELMAN 1997; Schwanen and Mokhtarian 2005) |
| Presence of Children | (Hamre and Buehler 2014; CERVERO and KOCKELMAN 1997) |
| Level of Education | (Hamre and Buehler 2014; MMWR 2015; Plaut 2005) |
| Possession of driver’s license | (CERVERO and KOCKELMAN 1997; Schwanen and Mokhtarian 2005) |
| Vehicle ownership | (CERVERO and KOCKELMAN 1997; Hamre and Buehler 2014) |
| Housing tenure (own or rent) | (CERVERO and KOCKELMAN 1997; Plaut 2005) |
| **Built Environment** |  |
| Population and employment density | (CERVERO and KOCKELMAN 1997; Hamre and Buehler 2014) |
| Land use mix (diversity) | CERVERO and KOCKELMAN 1997; Gehrke and Clifton |
| Design (Type of intersections; density of 4-way intersections) | CERVERO and KOCKELMAN 1997 |
| Distance to transit stops | CERVERO and KOCKELMAN 1997 |
| Distance to retail activities | (Cervero and Duncan 2003; CERVERO 1996) |
| Terrain or Slope | (Rodrı́guez and Joo, 2004) |
| **Trip Context** |  |
| Costs of travel | (Cervero, 1996) |
| Trip Purpose | (Cervero and Duncan 2003) |
| Travel Time | (Cervero, 1996; Hess, 2001) |
| Trip distance | (CERVERO and KOCKELMAN 1997; CERVERO 1996; Hamre and Buehler 2014) |
| Time of travel | Singleton and Wang (2013) |
| Safety and security | Singleton and Wang (2013) |
| **Transportation Supply and Services** | |
| Provisions of pedestrian, cycling and transit infrastructure | (Cervero and Duncan 2003; CERVERO and KOCKELMAN 1997; Hamre and Buehler 2014) |
| Level of service | (CERVERO and KOCKELMAN 1997; Cervero 1996; Hamre and Buehler 2014) |
| Parking (availability and price) | (Hamre and Buehler, 2014; Hess, 2001) |

## Model Form of Mode Choice Models

Table 2 summarizes the common structures of mode choice models. Discrete choice models of various specifications (Multinomial Logit Model & Nested Logit Model), binomial model, and log-odds model are the most common model forms of mode choice models in the literature.

**Table 1.2: Model Form of Mode Choice Models**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Model Form** | | **Dependent Variable** | **References** | |
| Discrete Choice Model (Multinomial logit-MNL) | Travel modes | | | (Cervero and Duncan, 2003; Rodrı́guez and Joo, 2004; Schwanen and Mokhtarian, 2005b; Singleton and Wang, 2014; Srinivasan and Ferreira, 2002; Train and McFadden, 1978; Ewing et al., 2004, Moeckel, 2015) |
| Discrete Choice Model (Nested logit-NL) | Travel modes with nested structure | | | (Hensher and Ton, 2000) |
| Binomial model  (a special case of MNL) | Choice of one mode versus other modes (e.g. driving alone or not; transit or not) | | | (Cervero, 1996; Cervero and Kockelman, 1997) |
| Log-odds | Probability of choosing mode versus other modes | | | (Hess, 2001) |
| Artificial neural networks (ANN) | Travel modes | | | (Hensher and Ton, 2000) |

## Travel Budget

### Household Travel Time Budget

Trip makers have specific daily travel time budgets, which can be related to their location of residence and modes of travel used during the day Zahavi (1974). Zahavi in research examined the stability of travel time budget. Zahavi and Ryan (1980, cited in Chen, 1999) argued that people spend a fixed percentage of their income on travel. They showed that an average car-owning household spent about 10% to 11 % of their income and carless households spent 3 to 5% of their income on travel. Zahavi (1974) in his study found that time and money budgets allocated to transportation differ within urban regions as a function of age, income and residential location, with location showing to be a better indicator of travel behavior than income. According to Gunn (1979), time spent traveling increases with increase in income. Travel time budget is strongly related to individuals and household characteristics (e.g income level, gender, employment status, and car ownership), attributes of activities at the destination (e.g activity duration), and characteristics of residential areas (e.g density, spatial structure and level of service) (Chen and Mokhtarian, 2008, Gunn, 1979). Travel time expenditure differs according to area types, with an increase in travel times in areas with higher densities. However, effects of area characteristics (e.g., density) on travel time expenditure are not as strong as the effects of individual and household characteristics (Chen and Mokhtarian, 2008, Gunn, 1979).Trip linking affects the number of trips that a traveler makes and therefore, in turn, affects her/his choice of using motorized or non-motorized mode of transport. There is a significant difference in a tripmaker's travel time budget as it depends on the combination of transport modes used by the traveler.

### Household Monetary Budget

There is a relationship between travel money expenditure and area density of a place. The amount of money spent on travel is lower in large urban areas than in small urban areas (Mokhtarian and Chen, 2004). According to Golob (1990) if travel decisions are made in a way that is consistent with a household utility-maximizing process subject to constraints associated with time or money budgets, then households will react to changing external conditions in a predictable way. Household travel expenditure is directly related to household income, as a percentage of either income or total expenditure. It is the lowest in the low-income groups and highest in the middle-income groups (Gunn, 1979). Goodwin (1981) also suggests that travel monetary expenditure varies among individuals and groups. However, household expenditure on travel expressed as a proportion of income is almost the same for car-owning households in same income groups and the same for a wide range of non-car-owning households.

According to (Goodwin, 1981), when time and money are added together and expressed as a single budget, the resulting generalized cost is relatively stable from different locations and over short periods of time, which would suggest possible trade-offs between travel time expenditure and travel money. Empirical studies have concluded that travel time and money expenditure is unlikely to remain constant over a wide range of circumstances (Tanner, 1982, Chen and Mokhtarian, 2008, Goodwin, 1981).

## Empirical Models

There are a number of empirical models that incorporate budget constraints in mode choice models.

### GreenSTEP Model

The GreenSTEP model simulates households’ travel characteristics and vehicle choice to study the effects of various polices on green house gas emission. The GreenSTEP model estimates vehicle ownership, fuel consumption, and GHG emissions at the individual household level. The model was designed to evaluate the sensitivity of household travel models to changes in various inputs. The model was estimated using disaggregated data because they model the responses of individual households. Households are assigned to various place types (metropolitan, other urban, or rural) and transportation characteristics. Each household is also assigned a density for their neighborhood of residence based on scenario inputs related to urban growth boundary policies. The households are also assigned public transit, freeway and arterial service levels based on the metropolitan area that they live in. The models in the GreenSTEP capture the responses of individual households to factors that affect vehicle travel.

GreenSTEP applies household travel budget and time constraints, which is used to account for effects of fuel prices and other variable costs such as fuel and carbon taxes on the amount of vehicle travel. It estimates household travel as a function of household income, number and ages of persons in the household, population density, and land use characteristics of the residence location, freeway supply, and public transit supply. The household spending on gasoline and other variable costs must be within a household transportation budget. Household travel costs are calculated from amounts of miles driven, fuel consumed, electricity consumed and GHG emitted (Gregor, 2012). GreenSTEP estimates the DVMT model which is concerned with all household travel for the effects and its effects on emissions and household budget. The DVMT model is a two-stage model; the first stage is a binomial logit model which predicts the probability of no vehicle travel on a given day, the second model is a linear model which predicts the amount of VMT given the vehicle travels. The average household VMT is estimated using linear regression, calculated as the ratio of vehicles to driving age persons in the household, income, the average cost per mile. It also includes a parking model to account for how much each household would pay based on scenario input assumptions.

Another model included in GreenSTEP is the household travel budget model. Households move expenses between transportation budget categories based on need. As long as a household can move expenditures among pieces of the transportation budget, the household’s response to changes in fuel prices can be inelastic. The model suggests that households in rural areas spent more money on gas than households in urban areas. However, this was offset by other vehicle expenses. If the fuel prices or other costs increase beyond the allocated transportation budget, the household will reduce their travel in direct proportion to increase in cost. According to estimates from the model, lower income households are more sensitive to changes in fuel prices.

### SmartGAP

The SmartGAP (later named RPAT) model was developed by RSG Inc, as disaggregated land-use transport model that predicts travel demand impacts at individual household level using place types (Resource Systems Group, Inc et al, 2013). Household place types are calculated using the four place types (urban core, close in community, suburban, and rural and 5 location categories (residential, commercial, mixed-use, transit oriented development, and Greenfield). The model also calculates the average daily miles traveled via auto and transit trips, which is sensitive to income, number of household vehicles, etc. The estimation of VMT by place types includes the job accessibility by auto variable. With job accessibility by auto being highest in the urban core and relatively lower in the other place types.

### SILO Model

The SILO model is an integrated land-use model representing various household constraints to household location, including the price of a dwelling, travel time to work and monetary transportation budget (Moeckel, 2011). It is designed as microscopic discrete choice models and simulates each household individually. The SILO model compares average income with average expenditures for households with different incomes. In anticipation of high energy prices, the model is designed so that households do not exceed their monetary budgets. If transportation costs exceed discretionary income (such as student loans, loans, etc) plus savings, the household will move either to a location closer to work or a less expensive dwelling and rearrange the share between housing and travel budgets.

Budget available for expenditures of household h

Income of household h

Are the parameters estimated

The SILO model uses this equation to analyze the impact of an increase in fuel costs and the adjusted transportation expenditures.

Where

Expenditures of household h for transportation

tc transportation costs (b for base case and s for alternative scenario)

el Elasticity of travel demand on transportation costs, set to -0.25

Transportation costs are calculated based on auto operating costs, the distance to work and transportation required for other purposes such as shopping, etc.

If the discretionary income and savings are insufficient to cover transportation costs for a given house, the utility for transportation costs at this dwelling is set to 0 (Moeckel, 2015).

If : = 0

If : =

Where

Utility of dwelling d for transportation budget tb

Parameters describing sensitivity of increased transportation costs

Discretionary expenditures of household h

Savings of household h

### IRPUD Model

The IRPUD model is another land use model that incorporate travel budget and mode choices (Wegener, 2011). In IRPUD, if transportation costs rise, low-income households may decide to locate closer to a location near work or chose a location with good transit services that may allow them to reduce the number of cars owned. The IRPUD model is divided in submodels, with the transport submodel seeking to identify and model the mobility patterns of a region. Households are segmented into different income groups. Under the transport submodel is the car ownership submodel. The car ownership submodel estimates the number of cars owned by households as a function of household travel budgets and expected travel expenditure. Below is the MNL model used to determine the mode choice is the IRPUD model.

(1)

Where

is the number of cars owned by households of income group q living in zone i,

household with a monthly travel budget

o and are the monthly costs of owning and parking a car in zone i

trips per month of households of type q for purpose g from zone i to zone j using mode m

out of pocket operating costs of such trips

This equation makes the assumption that households have to split their travel budgets between expenditures for trips and cars.

The amount of money each household is able and willing to pay given its car ownership level and number of trips is estimated as a deviation from the system mean travel cost proportional to the deviation of the household’s car ownership level from the regional average. See equation 2

(2)

According to Wegener (2011), zonal household travel budgets take into account the location of the household, with suburban households paying more for transport and less for housing than urban households.

(3)

Where

Is the utility of the trip

and are multiplicative weights adding up to 1

is the travel time of the trip

travel cost of the trip

amount of time the household is willing and able to pay per trip

and are value functions mapping travel time and cost of a common utility function

The logit model equation (4) is then used to calculate the destination and mode choice of households.

(4)

### Impact 2050

The Impacts 2050 model is a model that forecasts travel behavior. The model aims to address a wide range of questions by integrating the socio-demographic, land-use, employment, transport supply, and travel behavior (Impact 2050). To understand the relationships between population socio-economic characteristics and travel demand, and how these are impacted over time. A population’s impact on travel behavior is calculated regarding car ownership, trip rates, and mode choice (Impact 2050). It also looks at area types divided into three categories; urban (central city), suburban, and rural areas. The model emphasizes the importance of location decisions based on three categories; foreign migration (migration to and from other countries), Domestic migration (migration to and from other regions in the US), and intra-regional migration (relocation between area types within the same region). The model explores and compares the difference in the effects of the socio-demographics depending on the whether an individual was born in US or foreign born. According to the Impact 2050 mode choice model, age has a strong effect on mode choice with workers under 30 more likely to go as car passengers and the older age groups over 45 less likely to bike or walk. Area type also has strong effects on mode choice, with people in urban areas most likely to use transit and bike/walk for their work trips while those in rural areas are less likely to use these modes and more likely to drive or rideshare. The car ownership variable remained the most important variable in the model, as households with no car are likely to look for alternative means of modes of transport. The results also show that trip distance by all modes tends to increase with income while decrease with age.

## Data Sources

Since the choice of independent and dependent variables and specifications for mode choice models also depends on what information is available for model estimation and prediction, we explore the datasets available for model estimation, with a special focus on those with nation-wide coverage.

### National Household Travel Survey (NHTS)

NHTS is a microdata dataset with detailed social-demographic information of households and persons surveyed, and their vehicle and daily (travel day) trip level data (USDOT, Federal Highway Administration, 2009). The 2009 NHTS dataset contains data for 150,147 completed households nationwide. The mode choice (dependent variable) and socio-demographic variables, and trip context variables are sufficient for estimating mode choice models. However, the built environment variables and measures of transportation supply and services in the dataset fall short of information needed for a meaningful mode choice model specification. Chapter 2 discusses the built environment variables and measures of transportation supply and services variable included in NHTS. They are either too limited: for example, urban/rural indicators, population density (per squared miles), housing unit density, workers density, and percent of renter-occupied unit variables available at the block group level; or too coarse: for example, another set of density variables at the census tract level and heavy rail status at the MSA level. Most of the built environment and transportation supply and service variables identified in the literature are not available.

Unlike the regional household travel survey data, the geo-coordination or higher resolution geography identifier are not available in the NHTS data, which makes it impossible to join with a built environment database such as the Smart Location Database to get the information missing from the NHTS data.

### Regional Household Travel Surveys

Like NHTS data, regional household travel data, such as the Oregon Househod Activity Survey (OHAS), is a microdata dataset with detailed social-demographic information of households and persons surveyed, and their vehicle and daily (travel day) trip level data. The advantage of regional travel survey data is that the geo-coordination or higher resolution geography identifier may be obtained from the survey agency, and such information can be used to join it with built environment and transportation supply and service information. However, the process of retrieving and processing each dataset can be very tedious as each survey dataset may be in different format and coding, and it is unknown whether the data available will be representative. For example, models estimated from the OTAS data may not be easily transferrable to other states/regions – a goal of the RSMP tool, as Oregon is likely too unique in many ways. Such effort may only be worthwhile if data for one or multiple diverse regions can be obtained and processed.

### Smart Location Database

The Smart Location Database is a nationwide geographic data resource provided by EPA for measuring location efficiency (Ramsey and Bell, 2014). It includes more than 90 attributes summarizing characteristics such as housing density, diversity of land use, neighborhood design, destination accessibility, transit service, employment, and demographics. See Ramsey and Bell (2014) for a complete list of variables available. Most attributes are available for every census block group in the United States for 2010. Those variables are selected for their impacts to travel behavior, especially the 5D variables identified in the literature (Ewing and Cervero, 2010, 2001) as well as transportation supply and services, particularly the transit service. However, the Smart Location Database does not provide information on mode shares. Thus it alone will not be sufficient for estimating mode choice models. Provision of non-motorized transportation infrastructure (for example, bike lanes and cycle tracks) is not available in the Smart Location Database.

### Consumer Expenditure Survey

The Consumer Expenditure Survey (CE) provides a continuous and comprehensive flow of data on the buying habits of American consumers (US Bureau of Labor Statistics, 2014). These data are used widely in economic research and analysis, and in support of revisions of the Consumer Price Index. Bureau of Labor Statistics (BLS) provides two public used microdata: an **interview survey** containing data on monthly expenditures for housing, apparel and services, transportation, health care, entertainment, personal care, reading, education, food, tobacco, cash contributions, and personal insurance and pensions, as well as income and characteristics data, and **a diary survey** with data on weekly expenditures of frequently purchased items such as food at home, food away from home, alcoholic beverages, smoking supplies, personal care products and services, and nonprescription drugs, as well as income and characteristics data. Both surveys include detailed information of social-demographics including household income and housing characteristics that may be useful for estimating mode choice models. The interview survey includes vehicle ownership information, detailed out-of-pocket costs of transportation, such as vehicle operating expenses including vehicle repairing and maintenance, gasoline, and costs for using mass transit for various purposes (work, school, and other places). It also asks the surveyees about long trips (overnight trips or those longer than 75 miles), modes used and related costs.

The advantage of the CE data is that the information therein makes it easy to investigate monetary travel costs about overall household expenses (budget) and/or household income. There may be a possibility to infer mode shares from vehicle ownership, operating expenses, and costs of using mass transit, etc. However, since the CE dataset was not collected for such purpose, non-motorized travel is not reported; trip context, built environment and transportation supply and service variables are not available.

### Additional Datasets

The CDC Active Transportation Surveillance (Whitfield et al., 2015b) reviews national datasets that can be used for surveillance of active transportation usage in the US. The authors review not only datasets commonly used in travel behavior research such as American Community Survey and NHTS, but also datasets not so commonly used, such as the American Time Use Survey, National Health and Nutrition Examination Survey, and National Health Interview Survey. Not all of them are useful for the purpose of estimating mode choice models, as the health-focused surveys only partial mode information (active transportation mostly).

## Conclusion

Mode choice behavior is a core element of travel behavior and has significant implications in transportation planning and investment decision. Increasing shares of public transit and non-motorized modes of travel has been promoted as a potential policy lever to reach more sustainable urban development and as a policy goal itself. This project aims to enhance the mode choice module for Regional Strategic Planning Model that links policy inputs to more refined mode choice outcomes. Task 1 reviews the literature, explores available datasets and sets the stage for later tasks. The four categories of variables – socio-demographics, built environment, trip context and transportation supply, and services – identified in the literature are important to model household or individual level mode choice decision. On the data end, there is a challenge as nationwide data currently available are unable to provide a complete set of variables:

* Socio-demographic variables are influential and abundant in data with nationwide coverage (NHTS);
* Nationwide built environment and transportation supply/service (particularly transit) variables are available (Smart Location Database), but difficult to mesh with travel behavior (mode choices) and socio-demographic variable;
* Regional data can be meshed to get all necessary information but may post a challenge of transferability and requires extra data processing.

So far, the ideal solution would be to get access to the NHTS dataset joined with Smart Location Database. If such dataset cannot be accessed early in the project, an alternative would be a consolidation of regional travel survey data from diverse regions for similar years (ideally circa 2010), which can be then joined with the Smart Location Database or other data sources for built environment information. Consumer Expenditure Survey data would be the third option.

# REFERENCES

Cervero, R., 1996. Mixed land-uses and commuting: evidence from the American Housing Survey. Transportation Research Part A: Policy and Practice 30, 361–377.

Cervero, R., Duncan, M., 2003. Walking, Bicycling, and Urban Landscapes: Evidence From the San Francisco Bay Area. American Journal of Public Health 93, 1478–1483.

Cervero, R., Kockelman, K., 1997. Travel Demand and the 3Ds: Density, Diversity, and Design. Transportation Research Part D: Transport and Environment 2, 199–219. doi:10.1016/S1361-9209(97)00009-6

Ewing, R., Cervero, R., 2010. Travel and the Built Environment. Journal of the American Planning Association 76, 265–294. doi:10.1080/01944361003766766

Ewing, R., Cervero, R., 2001. Travel and the Built Environment: A Synthesis. Transportation Research Record: Journal of the Transportation Research Board 1780, 87–114. doi:10.3141/1780-10

Hamre, A., Buehler, R., 2014. Commuter Mode Choice and Free Car Parking, Public Transportation Benefits, Showers/Lockers, and Bike Parking at Work: Evidence from the Washington, DC Region. Journal of Public Transportation 17.

Heinen, E., Wee, B. van, Maat, K., 2010. Commuting by Bicycle: An Overview of the Literature. Transport Reviews 30, 59–96. doi:10.1080/01441640903187001

Hensher, D.A., Ton, T.T., 2000. A Comparison of the Predictive Potential of Artificial Neural Networks and Nested Logit Models for Commuter Mode Choice. Transportation Research Part E: Logistics and Transportation Review 36, 155–172. doi:10.1016/S1366-5545(99)00030-7

Hess, D., 2001. Effect of Free Parking on Commuter Mode Choice: Evidence from Travel Diary Data. Transportation Research Record: Journal of the Transportation Research Board 1753, 35–42. doi:10.3141/1753-05

Plaut, P.O., 2005. Non-Motorized Commuting in the Us. Transportation Research Part D: Transport and Environment 10, 347–356. doi:10.1016/j.trd.2005.04.002

Ramsey, K., Bell, A., 2014. Smart Location Database User Guide. US Environment Protection Agency.

Resource Systems Group, Inc, Fehr & Peers, Robert Cervero, Kara Kockelman, and Renaissance Planning Group, 2013. SmartGAP User’s Guide, Transportation Research Board of the National Academies, Washington, DC.

Rodrı́guez, D.A., Joo, J., 2004. The Relationship Between Non-Motorized Mode Choice and the Local Physical Environment. Transportation Research Part D: Transport and Environment 9, 151–173. doi:10.1016/j.trd.2003.11.001

Schwanen, T., Mokhtarian, P., 2005a. What Affects Commute Mode Choice: Neighborhood Physical Structure or Preferences Toward Neighborhoods? Journal of Transport Geography 83–99.

Schwanen, T., Mokhtarian, P.L., 2005b. What Affects Commute Mode Choice: Neighborhood Physical Structure or Preferences Toward Neighborhoods? Journal of Transport Geography 13, 83–99. doi:10.1016/j.jtrangeo.2004.11.001

Singleton, P., Wang, L., 2014. Safety and Security in Discretionary Travel Decision Making. Transportation Research Record: Journal of the Transportation Research Board 2430, 47–58. doi:10.3141/2430-06

Srinivasan, S., Ferreira, J., 2002. Travel Behavior at the Household Level: Understanding Linkages with Residential Choice. Transportation Research Part D: Transport and Environment 7, 225–242. doi:10.1016/S1361-9209(01)00021-9

Train, K., McFadden, D., 1978. The Goods/Leisure Tradeoff and Disaggregate Work Trip Mode Choice Models. Transportation Research 12, 349–353. doi:10.1016/0041-1647(78)90011-4

US Bureau of Labor Statistics, 2014. Consumer Expenditure Survey. US Bureau of Labor Statistics.

USDOT, Federal Highway Administration, 2009. National Household Travel Survey.

Whitfield, G.P., Paul, P., Wendel, A.M., 2015a. Active Transportation Surveillance - United States, 1999-2012 (Morbidity and Mortality Weekly Report), Surveillance Summaries Vol 64. No. 7. Centers for Disease and Control and Prevention, Atlanta, GA.

Whitfield, G.P., Paul, P., Wendel, A.M., 2015b. Active Transportation Surveillance - United States, 1999-2012 (Morbidity and Mortality Weekly Report), Surveillance Summaries Vol 64. No. 7. Centers for Disease and Control and Prevention, Atlanta, GA.