

# **Re-examining the influence of work and non-work accessibility on residential location choices with a micro-analytic framework**

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# Overview

Re-examining the influence of work and non-work **accessibility** on **residential location** choices with a **micro-analytic** framework

- **Residential location** – anchor for travel behavior; important in land use-transport link
- **Accessibility** – Access to activities; important?
- **Micro-analytic** – Disaggregate, activity-based

# Presentation Outline

- Integrated Modeling Context
- Discrete Choice Analysis
- Residential Location Application
- Accessibility
- Model Results
- Research Extensions
- Questions & Answers

## ➤ Integrated Modeling Context

Discrete Choice  
Analysis

Residential Location  
Application

Accessibility

Model Results

Research Extensions

Questions & Answers

- Traditional transportation engineering, narrow focus:

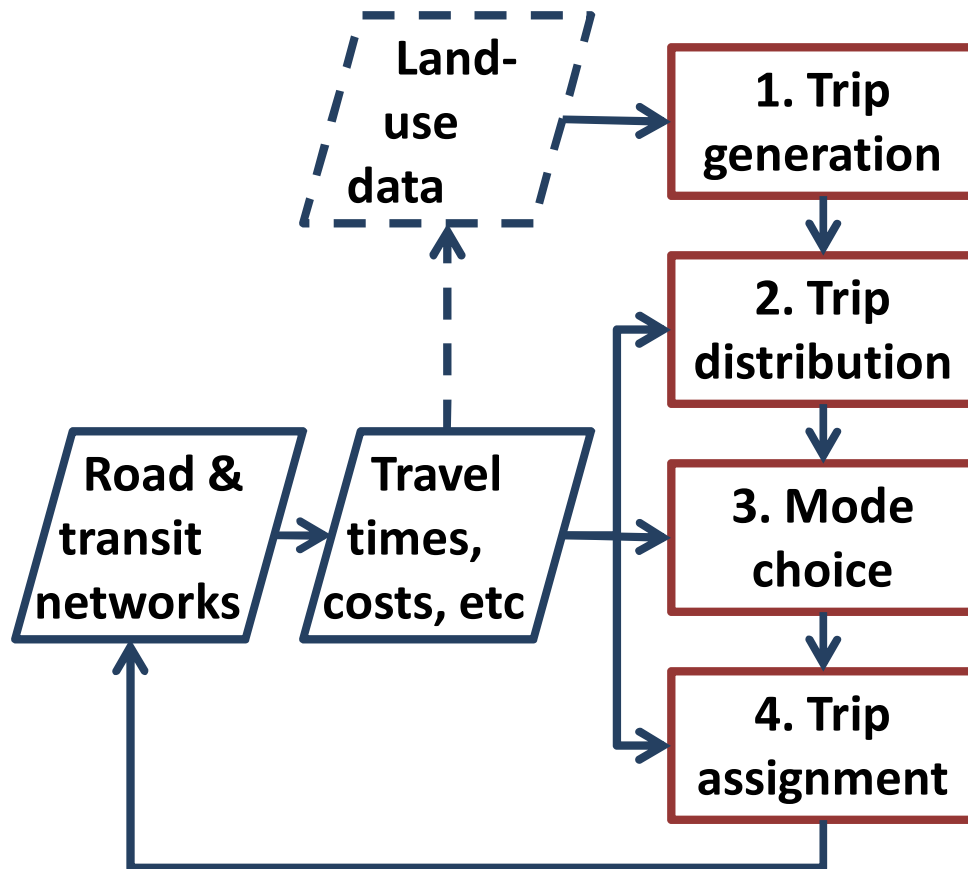
*Safe & efficient movement of  
people & goods*

- Designs: structural/geometric
- Materials
- Operations management
- **Demand forecasting**

# Travel Demand Models

- System performance analysis
- Planning & policy evaluation
  - Land use regulations (Urban Planning)
  - Political decisions (Public Policy)
- Supply & demand for travel
- Most common in operations:  
“Four-step” travel demand model

# “Four-step” Travel Demand Model



1. How many trips?  
What purpose?
2. To where?
3. Which mode?
4. What route?

- **Trip-based**
- **Zonal geography**
- **Land use: exogenous!**

# Paradigm Shifts

- Travel demand model
  - **integrated land use & transportation models**
    - Feedback loops & other complex interactions
    - Competing society & stakeholder values
    - Convergence of options for interventions
- Trip-base → **activity-based**
- Aggregation → **disaggregation**
  - Geography
  - Agent-based behaviors

# Related Travel Decisions

- Auto ownership
- Employment choice
- Business location
- Development location
- **Residential location**
  - Vital anchor point for travels/activities
  - Consider different time scales

## Integrated Modeling Context

### ➤ **Discrete Choice Analysis**

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- Discrete choice theory (McFadden 1978; 2000 Nobel Prize in Economics)
- Individual choice behavior (consumption)  
➔ aggregate demand

# Discrete Choice Model Assumptions

## Decision maker ( $n$ )

- Who/what; characteristics

## Alternatives ( $i$ )

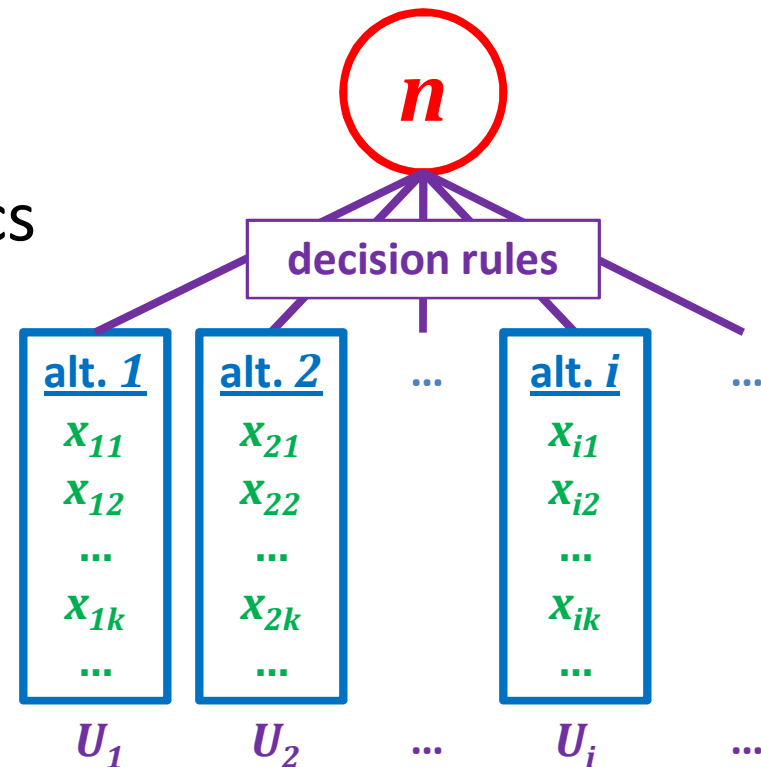
- Possible choices

## Attributes ( $x_{ik}$ )

- Decision factors

## Decision rules

- Process to make choice
- E.g., Random Utility Models ( $U_i$ )



# Random Utility Maximizations

- **Probabilistic** approach; alt.  $i$  being chosen:

$$P(i) = P \left[ U_i = \max_j U_j \right]$$

- **Utility function:** deterministic & random parts

$$U_i = V_i + \epsilon_i \quad \text{where} \quad V_i = \beta \cdot x_i$$

- **Multinomial Logit (MNL)** formulation:  
Assume  $\epsilon_j$  independently & identically distributed with a Gumbel distribution

$$P(i) = \frac{e^{V_i}}{\sum_j e^{V_j}}$$

# Residential Location Choice


- Decision makers: **households** (HH)
- Alternatives: varying degrees of aggregation
  - Zones
  - Neighborhoods
  - Gridcells (e.g., 150m x 150m)
  - Parcels
  - **Buildings**
  - Units

# Residential Location Choice Set

- **Universal set** of alternatives
  - Up to millions (buildings/units)
- **Trade-offs:** aggregation & feasibility/efficiency
  - Highly aggregated & computational efficiency
  - Highly disaggregated & infeasible/unrealistic set
- **Sampling** of alternatives
  - Multinomial Logit: consistent estimates of parameters with sampled subset
  - Sampling weights (e.g., number of units/building)

# Residential Location Choice Attributes

For household  $n$  with characteristics  $y_n$  & alternative  $i$  with attributes  $x_n$

$$V_i^n = \sum_1^K \beta_{ik} x_{ik} + \sum_1^L \alpha_{il} (x_{il} y_n)$$


## Alternative Variables

- unit size
- neighborhood composition
- accessibility to CBD
- $\vdots$

## Interaction Variables

- price x income
- young neighborhood x young HH
- apartment x renter
- $\vdots$

(aggregation: averages or distribution; disaggregation: specific values)

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## Central Puget Sound Region

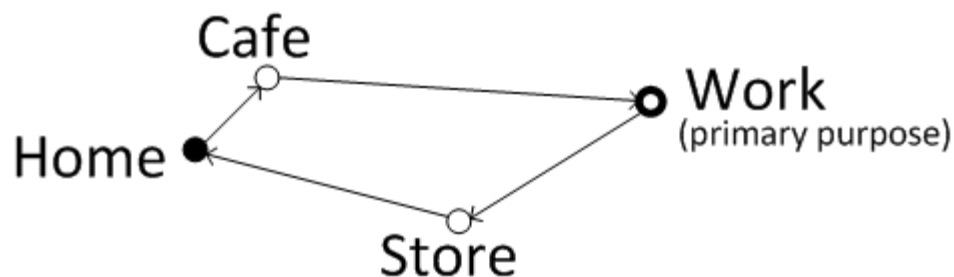
- 6,290 mi<sup>2</sup>
- 82 towns & cities
- 3.5+ mil. people
- 1.1 mil. buildings

## Datasets

- Socio-economic, land, travel, geo-spatial
- **2006 HH Activity Survey**

# 2006 HH Activity Survey

- 2-day activity/travel survey
- 4,739 HH & 10,516 persons
  - Model: subset of recent movers for temporal consistency (1,677 HH)
- Current & past home & workplace locations
- Tour/trip-chain (e.g., home-based work tour)



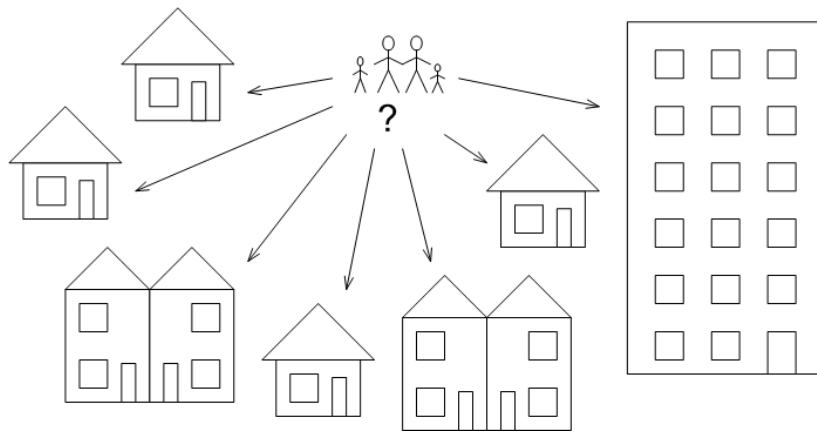
# 2006 HH Activity Survey Tours

Descriptive statistics:

- Person-tours: 27,306
- **Work tours: 9,257 (34%)**
  - 50.1% at least 1 stop other than work
  - 20.2% made stop before work
  - 41.9% made stop after work
  - Majority of stops for shopping, eating out, & personal business

# Puget Sound Region Residential Location Choice Model

- Discrete choice, random utility maximization
- Multinomial Logit formulation



- HH level decisions
- Building level alternatives (believed to be 1<sup>st</sup> such application)

- Alternative attributes (e.g., building specific qualities for control; accessibilities)

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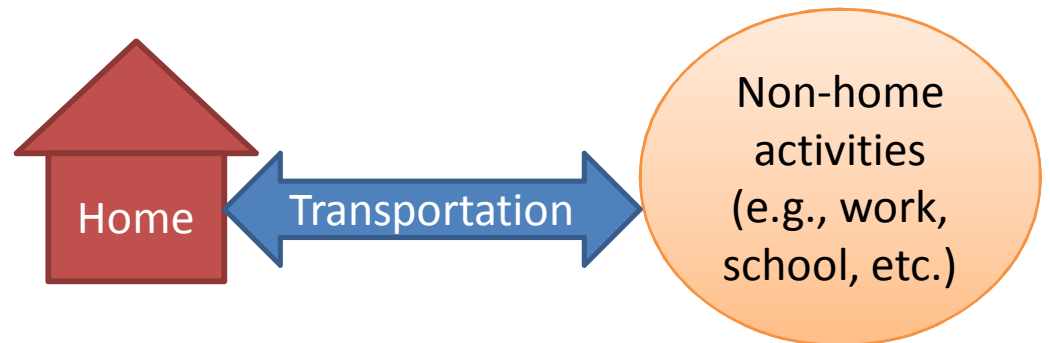
➤ **Accessibility**

Model Results

Research Extensions

Questions & Answers

- Accessibility concept: ties land use & transportation



- Measurements vary in complexity & ability to capture concept

# Unresolved Issues

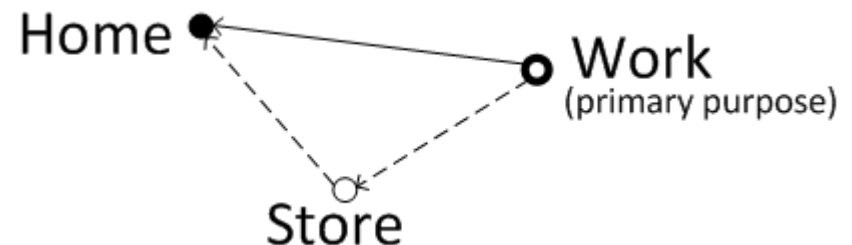
- Households (HH) with 0 or 2+ workers?
- Non-work accessibility?
- Trip-chaining? (Tours?)
- **Accessibility no longer important?**  
(Hamilton 1982; Small & Song 1992; Giuliano & Small 1993; Gordon & Richardson 1995)
  - Multiple-worker HH & dispersion of employment
  - Competition with access to other amenities

# Types of Accessibility

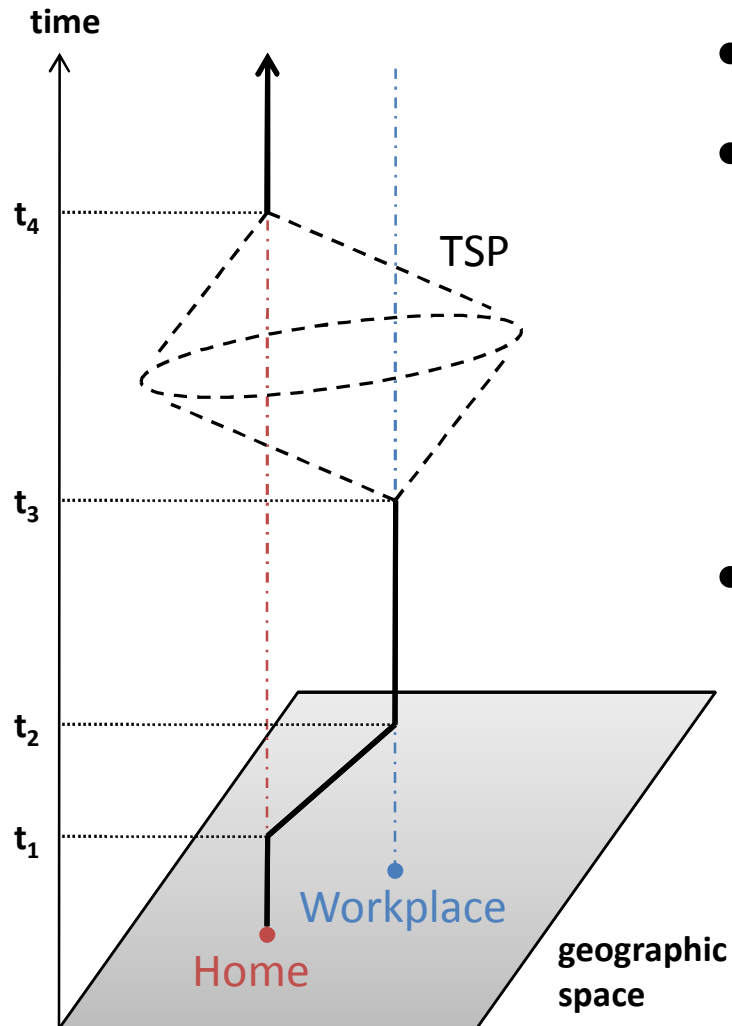
- **General accessibility**
  - Only place-specific (home-based)
  - Travel costs (e.g., travel time to CBD)
  - Opportunities (e.g., shops within X distance)
- **Individual-specific accessibility**
  - Place- & person-specific (e.g., home-workplace travel time)

# Time-Space Prism Approach

- **Time geography** (Hägerstrand 1970; Miller 1999)
- Explicitly recognizes **time-space constraints**
- Compliments **activity-based** models
- Considers trip-chaining:  
access to **discretionary**  
activities between  
**mandatory** activities



# Time-Space Prism (TSP)



Accessibility

- At individual worker level
- **Constraints**
  - *Spatial*: home & workplace
  - *Temporal*: home & work schedules
  - *Travel*: transportation network & travel speeds
- Application: **work-to-home trips**
  - Used survey departure & arrival times for those who made >1 stop (joint distribution)
  - Randomly assigned to each worker

# TSP Accessibility Measure

- Accessible zones
  - Identify **feasible set** of traffic analysis zones
  - Based on spatial & temporal constraints
  - Used travel speeds from network travel model
- Accessibility opportunity set
  - Number of **consumer type jobs** (in retail, food & other services sectors)

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## ➤ **Model Results**

Research Extensions

Questions & Answers

Model process (5 models)

- Base model estimation (control variables only)
- Add accessibility variables
  - Regional work
  - Neighborhood shops
  - Individual work travel time
  - Individual TSP shop ops.

**Table A: Explanatory variables for household location choice models**

Variables	Descriptions
residential_units	Log of number of residential units in building
same_area_type	Dummy of building in same area type as previous household (HH) location
same_area	Dummy of building in same area as previous HH location
Kitsap	Dummy of building in Kitsap County
population_density	Log of zonal population density
high_inc_x_size	High HH income (inc) dummy x log of average dwelling size (sq ft/unit)
mid_inc_x_size	Mid HH inc dummy x log of average dwelling size (sq ft/unit)
low_inc_x_size	Low HH inc dummy x log of average dwelling size (sq ft/unit)
disposable_inc	log of HH inc less average dwelling price per unit
inc_x_condo	Log of HH inc x building is condo residential dummy
inc_x_MFR	Log of HH inc x building is multi-family residential dummy
kids_x_SFR	Dummy of HH with children x is single-family residential dummy
kids_x_kids_HH	Dummy of HH with children x percent HH with children within walking distance (600m)
one_pers_x_not_SFR	One person HH dummy x building is not single-family residential dummy
renter_x_is_MFR	Renter HH dummy x building is multi-family residential dummy
young_x_young_HH	Young HH (average adult age $\leq 30$ ) dummy x percent young HH within walking distance (600m)
<i>Accessibility variables</i>	
average_logsum	Trip weighted zonal average logsum for AM home-based-work (HBW) drive alone trips
neigh_shopping	Log of number of shopping type jobs (retail, food, & other services) within walking distance
work_travel_time	Travel time for AM HBW drive alone trips to workplace (maximum between up to 2 workers)
TSP_shopping	Log of number of shopping type jobs (retail, food, & other services) in time-space prism for the work-to-home leg of the HBW tour (maximum between up to 2 workers)

**Table B: Estimation results for residential location choice models**

Variables	(1) Base Model		Accessibility Models							
	coeff.	t-val.	(2) General		(3) Neighborhood		(4) Workplace		(5) Work-to-home	
			coeff.	t-val.	coeff.	t-val.	coeff.	t-val.	coeff.	t-val.
residential_units	0.674	18.0	0.721	17.6	0.692	17.4	0.629	16.1	0.638	16.2
same_area_type	0.414	4.11	0.417	4.12	0.303	2.87	0.349	3.40	0.380	3.80
same_area	2.65	26.3	2.66	26.4	2.80	27.0	2.34	23.3	2.53	24.3
Kitsap	0.916	9.68	0.830	8.39	0.866	8.50	1.76	14.7	1.73	14.4
population_density	0.0165	0.661	-0.0495	-1.49	-0.101	-2.90	-0.199	-5.48	-0.247	-6.77
high_inc_x_size	0.971	11.6	0.952	11.3	1.01	11.9	0.816	9.67	0.892	10.5
mid_inc_x_size	-0.330	-8.85	-0.333	-8.24	-0.304	-7.55	-0.313	-7.86	-0.311	-7.30
low_inc_x_size	-0.306	-5.37	-0.335	-6.46	-0.320	-5.50	-0.291	-4.67	-0.330	-5.49
disposable_inc	0.0631	3.20	0.0492	2.44	0.0657	3.23	0.0672	3.16	0.0714	3.31
inc_x_condo	0.0539	3.11	0.0405	2.17	0.0479	2.52	0.0524	2.81	0.0591	3.25
inc_x_MFR	-0.117	-6.27	-0.126	-6.54	-0.127	-6.52	-0.136	-6.90	-0.134	-6.91
kids_x_SFR	0.565	2.80	0.647	3.21	0.743	3.53	0.518	2.46	0.610	2.93
kids_x_kids_HH	0.0139	2.85	0.0120	2.45	0.0186	3.73	0.0262	5.13	0.0212	4.20
one_pers_x_not_SFR	0.688	4.33	0.575	3.40	0.581	3.46	0.773	4.70	0.740	4.37
renter_x_is_MFR	2.85	14.6	2.90	14.5	3.05	15.0	2.84	14.0	3.00	14.7
young_x_young_HH	0.0211	5.18	0.0247	5.55	0.0206	4.82	0.0220	4.98	0.0235	5.38
<b>Accessibility variables</b>										
average_logsum			0.635	3.06	0.573	2.88	0.711	3.61	0.808	3.84
neigh_shopping					0.0715	3.88	0.0566	3.05	0.0507	2.70
work_travel_time							-0.0248	-21.1	-0.0227	-17.6
TSP_shopping									0.0473	3.37
Log-likelihood (LL)		-3954.9		-3934.0		-3898.2		-3697.5		-3642.0
Adj. likelihood ratio ( $\rho'$ )		0.30381		0.30730		0.31341		0.34841		0.35797
$\chi^2$ likelihood test		n/a	Reject model (1) at >99.9% confid.		Reject model (2) at >99.9% confid.		Reject model (3) at >99.9% confid.		Reject model (4) at >99.9% confid.	

N = 1677; Null log-likelihood = -5703.8

# Estimation Result Highlights

Variables	(1) Base	Accessibility Models							
		(2) Regional work		(3) Neigh. shops		(4) Individ. work TT		(5) Individ. TSP shop ops.	
		coeff.	t-val.	coeff.	t-val.	coeff.	t-val.	coeff.	t-val.
Control variables									
...									
<b>Accessibility variables</b>									
average_logsum		0.64	3.1	0.57	2.9	0.71	3.6	0.81	3.8
neigh_shopping				0.072	3.9	0.057	3.1	0.051	2.7
work_travel_time						-0.025	-21	-0.023	-18
TSP_shopping								0.048	3.4
Log-likelihood (LL)	-3954.9								
Adj. likelihood ratio ( $\rho'$ )	0.30381	-3934.0		-3898.2		-3697.5		-3642.0	
$\chi^2$ likelihood test	n/a	Reject (1) at >99.9%		Reject (2) at >99.9%		Reject (3) at >99.9%		Reject (4) at >99.9%	

N = 1677; Null log-likelihood = -5703.8

# Relative Influence of Variables

- Use estimated parameters & utility function

Estimated Parameters ( $\beta$ )

$$\left[ \begin{array}{l} \text{alt. } i \\ \beta_{i1} x_{i1} + \\ \beta_{i2} x_{i2} + \\ \dots \\ \beta_{ik} x_{ik} + \\ \dots \\ = U_i \end{array} \right]$$

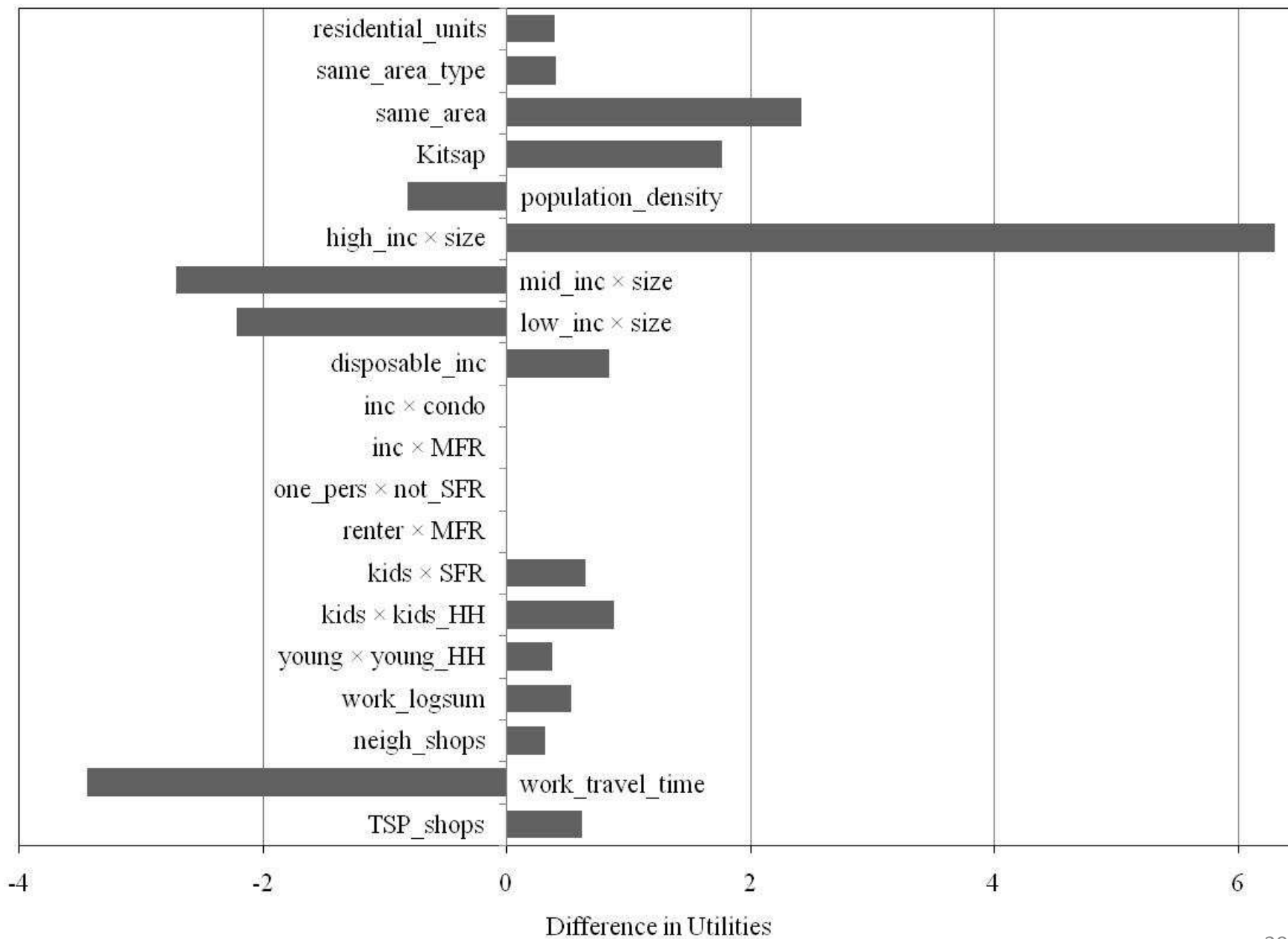
All variables ( $x$ ) except one held at median value

One variable:

- Use 5<sup>th</sup> & 95<sup>th</sup> percentile values
- Calc.  $\Delta U$  for indication of influence

- (HH income) x (building size): greatest influence
- Individual work travel time: 2<sup>nd</sup> overall
- Individual TSP shop ops.: 2<sup>nd</sup> highest accessibility

**Figure 1: Difference in utilities between the 5th and 95th percentile values**



# Conclusions

- **Accessibility** still matters for residential choice
  - Work & discretionary activities
- **Time-space prism** constrained approach
  - Theoretically sound for accessibility measurement
  - Captures trip-chaining discretionary activities
- **Disaggregate** approach
  - Captures omitted variables
  - Activity-based micro-simulation

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➤ **Research Extensions**

Questions & Answers

- Travel choices
- Modeling structures
- Model est. approaches
- Sampling procedures

# MNL Models: Pros & Cons

- **Closed & tractable** mathematical form
- Allows **random sampling**
- Assumption: **Independence from Irrelevant Alternatives (IIA)**
  - Shared attributes
  - Related choices

# Residential Mobility & Relocation

- Examined & modeled individually to great extent
- Explore underlying connections between them
- Propose **Nested Logit (NL)** model to explore underlying connections
- Contribute to modeling of these behaviors

# Nested Logit Model of Mobility & Relocation Choices

Mobility choice (m)

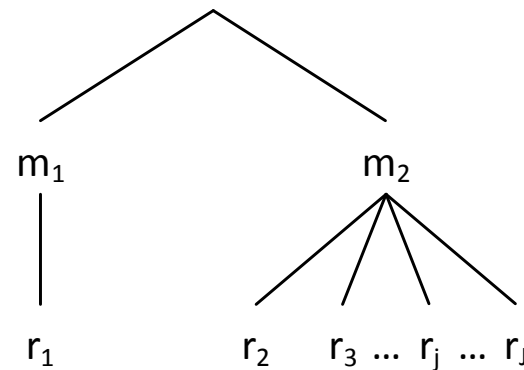
$m_1 = \text{stay}$

$m_2 = \text{move}$

Relocation choice (r)

$r_1 = \text{stay location}$

$r_j = \text{move locations, } j = 2, \dots, J$



Observations (N = 4,730)

$r_1$

$r_2, \dots, r_{30}$

Stayers ( $N_{\text{stayers}} = 3,062$ )

chosen alt.

randomly sampled

Movers ( $N_{\text{movers}} = 1,677$ )

previous  
location

$r_2 = \text{chosen alt.}$

$r_3, \dots, r_{30} = \text{randomly sampled}$

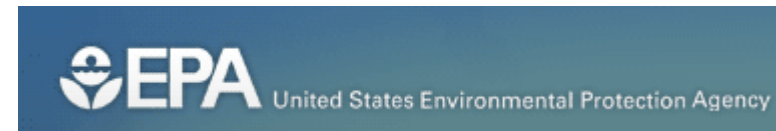
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**THANK YOU!**

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# Chi Square Likelihood Ratio Test

$$\chi^2[-2(LL_{\beta,R} - LL_{\beta,U})] = \text{significance level for rejection}$$

where

$\chi^2$ : chi-squared distribution function

$LL_{\beta,R}$ : log likelihood value of the restricted (base) model

$LL_{\beta,U}$ : log likelihood value of the unrestricted model