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

Brian H. Y. Lee

Dept. of Urban Design & Planning
University of Washington

1 May 2009

Transportation Seminars
Center for Transportation Studies
Portland State University
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
• 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 $\epsilon_i$ 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)
For household $n$ with characteristics $y_n$ & alternative $i$ with attributes $x_n$

$$V^n_i = \sum_{k=1}^{K} \beta_{ik} x_{ik} + \sum_{l=1}^{L} \alpha_{il} (x_{il} y_n)$$

**Alternative Variables**
- unit size
- neighborhood composition
- accessibility to CBD
  
**Interaction Variables**
- price x income
- young neighborhood x young HH
- apartment x renter

(aggregation: averages or distribution; disaggregation: specific values)
Central Puget Sound Region
• 6,290 mi²
• 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)

Residential Location Application
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 1st such application)

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

![Diagram of Home, Work, and Store]
Time-Space Prism (TSP)

- 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)
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>
<thead>
<tr>
<th>Variables</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>residential_units</strong></td>
<td>Log of number of residential units in building</td>
</tr>
<tr>
<td><strong>same_area_type</strong></td>
<td>Dummy of building in same area type as previous household (HH) location</td>
</tr>
<tr>
<td><strong>same_area</strong></td>
<td>Dummy of building in same area as previous HH location</td>
</tr>
<tr>
<td><strong>Kitsap</strong></td>
<td>Dummy of building in Kitsap County</td>
</tr>
<tr>
<td><strong>population_density</strong></td>
<td>Log of zonal population density</td>
</tr>
<tr>
<td><strong>high_inc_x_size</strong></td>
<td>High HH income (inc) dummy x log of average dwelling size (sq ft/unit)</td>
</tr>
<tr>
<td><strong>mid_inc_x_size</strong></td>
<td>Mid HH inc dummy x log of average dwelling size (sq ft/unit)</td>
</tr>
<tr>
<td><strong>low_inc_x_size</strong></td>
<td>Low HH inc dummy x log of average dwelling size (sq ft/unit)</td>
</tr>
<tr>
<td><strong>disposable_inc</strong></td>
<td>Log of HH inc less average dwelling price per unit</td>
</tr>
<tr>
<td><strong>inc_x_condo</strong></td>
<td>Log of HH inc x building is condo residential dummy</td>
</tr>
<tr>
<td><strong>inc_x_MFR</strong></td>
<td>Log of HH inc x building is multi-family residential dummy</td>
</tr>
<tr>
<td><strong>kids_x_SFR</strong></td>
<td>Dummy of HH with children x is single-family residential dummy</td>
</tr>
<tr>
<td><strong>kids_x_kids_HH</strong></td>
<td>Dummy of HH with children x percent HH with children within walking distance (600m)</td>
</tr>
<tr>
<td><strong>one_pers_x_not_SFR</strong></td>
<td>One person HH dummy x building is not single-family residential dummy</td>
</tr>
<tr>
<td><strong>renter_x_is_MFR</strong></td>
<td>Renter HH dummy x building is multi-family residential dummy</td>
</tr>
<tr>
<td><strong>young_x_young_HH</strong></td>
<td>Young HH (average adult age ≤ 30) dummy x percent young HH within walking distance (600m)</td>
</tr>
</tbody>
</table>

**Accessibility variables**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>average_logsum</strong></td>
<td>Trip weighted zonal average logsum for AM home-based-work (HBW) drive alone trips</td>
</tr>
<tr>
<td><strong>neigh_shopping</strong></td>
<td>Log of number of shopping type jobs (retail, food, &amp; other services) within walking distance</td>
</tr>
<tr>
<td><strong>work_travel_time</strong></td>
<td>Travel time for AM HBW drive alone trips to workplace (maximum between up to 2 workers)</td>
</tr>
<tr>
<td><strong>TSP_shopping</strong></td>
<td>Log of number of shopping type jobs (retail, food, &amp; other services) in time-space prism for the work-to-home leg of the HBW tour (maximum between up to 2 workers)</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>residential_units</td>
<td>0.674</td>
</tr>
<tr>
<td>same_area_type</td>
<td>0.414</td>
</tr>
<tr>
<td>same_area</td>
<td>2.65</td>
</tr>
<tr>
<td>Kitsap</td>
<td>0.916</td>
</tr>
<tr>
<td>population_density</td>
<td>0.0165</td>
</tr>
<tr>
<td>high_inc_x_size</td>
<td>0.971</td>
</tr>
<tr>
<td>mid_inc_x_size</td>
<td>-0.330</td>
</tr>
<tr>
<td>low_inc_x_size</td>
<td>-0.306</td>
</tr>
<tr>
<td>disposable_inc</td>
<td>0.0539</td>
</tr>
<tr>
<td>inc_x_condo</td>
<td>0.0539</td>
</tr>
<tr>
<td>inc_x_MFR</td>
<td>-0.117</td>
</tr>
<tr>
<td>kids_x_SFR</td>
<td>0.565</td>
</tr>
<tr>
<td>kids_x_kids_HH</td>
<td>0.0139</td>
</tr>
<tr>
<td>one_pers_x_not_SFR</td>
<td>0.688</td>
</tr>
<tr>
<td>renter_x_is_MFR</td>
<td>2.85</td>
</tr>
<tr>
<td>young_x_young_HH</td>
<td>0.0211</td>
</tr>
</tbody>
</table>

**Accessibility variables**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>average_logsum</td>
<td>0.635</td>
<td>3.06</td>
<td>0.573</td>
<td>2.88</td>
<td>0.711</td>
<td>3.61</td>
<td>0.808</td>
<td>3.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>neigh_shopping</td>
<td>0.0715</td>
<td>3.88</td>
<td>0.0566</td>
<td>3.05</td>
<td>0.0507</td>
<td>2.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>work_travel_time</td>
<td>-0.0248</td>
<td>-21.1</td>
<td>-0.0227</td>
<td>-17.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSP_shopping</td>
<td>0.0473</td>
<td>3.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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                 |
χ² 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

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1) Base</th>
<th>Accessibility Models</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control variables</td>
<td>Accessibility variables</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>=logsum=0.64=3.1</td>
<td>0.57 2.9</td>
<td>0.71 3.6</td>
</tr>
<tr>
<td>neigh_shopping=0.072=3.9</td>
<td>0.057 3.1</td>
<td>0.051 2.7</td>
</tr>
<tr>
<td>work_travel_time=-0.025 21</td>
<td></td>
<td>-0.023 -18</td>
</tr>
<tr>
<td>TSP_shopping=0.048 3.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Log-likelihood (LL)  
-3954.9  -3934.0  -3898.2  -3697.5  -3642.0

Adj. likelihood ratio (ρ’)  
0.30381  0.30730  0.31341  0.34841  0.35797

χ² 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

\[
\text{alt. } i = \beta_{i1} x_{i1} + \beta_{i2} x_{i2} + \ldots + \beta_{ik} x_{ik} + \ldots = U_i
\]

- Estimated Parameters (\( \beta \))
- All variables (\( x \)) except one held at median value
- One variable:
  - Use 5\(^{th}\) & 95\(^{th}\) percentile values
  - Calc. \( \Delta U \) for indication of influence

• (HH income) \( \times \) (building size): greatest influence
• Individual work travel time: 2\(^{nd}\) overall
• Individual TSP shop ops.: 2\(^{nd}\) highest accessibility
Figure 1: Difference in utilities between the 5th and 95th percentile values

- residential_units
- same_area_type
- same_area
- Kitsap
- population_density
- high_inc × size
- mid-inc × size
- low_inc × size
- disposable_inc
- inc × condo
- inc × MFR
- one_person × not_SFR
- renter × MFR
- kids × SFR
- kids × kids_HH
- young × young_HH
- work_logsum
- neigh_shops
- TSP_shops
- work_travel_time
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
- 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)
- \( r_1 = \text{stay location} \)
- \( r_j = \text{move locations}, j = 2, \ldots, J \)

Observations (N = 4,730)

<table>
<thead>
<tr>
<th>Stayers (N_{stay} = 3,062)</th>
<th>Movers (N_{move} = 1,677)</th>
</tr>
</thead>
<tbody>
<tr>
<td>chosen alt.</td>
<td>previous location</td>
</tr>
<tr>
<td>randomly sampled</td>
<td>( r_2 = \text{chosen alt.} )</td>
</tr>
<tr>
<td></td>
<td>( r_3, \ldots, r_{30} = \text{randomly sampled} )</td>
</tr>
</tbody>
</table>
Acknowledgements

Dr. Paul A. Waddell
Liming Wang
Dept. of Urban Design & Planning
University of Washington

Dr. Ram M. Pendyala
Dept. of Civil & Environmental Engineering
Arizona State University
THANK YOU!

Contact information:
Brian H. Y. Lee
bhylee@u.washington.edu
Chi Square Likelihood Ratio Test

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

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