An Activity-related Land Use Mix Construct and Its Connection to Pedestrian Travel

Steven R. Gehrke
Portland State University
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Civil & Environmental Engineering
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Research context

Sustained popularity toward investigating transportation-land use interactions

• Prospect to moderate travel behavior by physically altering our urban landscape

Increased adoption of policies focused on land use mixing

• Smart growth communities and mixed use developments
• Improve BE efficiencies increase local accessibility and encourage walking
Research interest

Multidisciplinary interest

• Reduce auto-related travel behaviors, balance travel demand, promote tour complexity
• Promote urban revitalization, slow rural land consumption, increase visible interest
• Higher rates of physical activity, reduced vehicle emissions, mental health benefits

Remains a goal without an established set of indicators

• Variety of metrics evaluating effectiveness of programs or policies in relation to travel
• Misguidance of practice by adoption of measures with imperfect theoretical foundations
Land use mix measurement

Accessibility
Ease of an individual to reach an opportunity from a location

Theorized link to travel
Reduced distance between locations increases feasibility of walking by diminishing competitive edge of faster modes

Shortcomings
• Only measures distance between two activity locations
• Provides summary calculation for only the origin

Accessibility Measures
• Distance-based

0.25 miles
Land use mix measurement

Intensity
Count of locations or percent of area related to land use type

Theorized link to travel
Increased intensity of activity locations enhances practicality of walking to fulfill a variety of daily life activities

Shortcomings
- Inability to summarize intensity of multiple land use types
- Sensitive to chosen spatial extent for operationalization

Intensity Measures
- Count-based
- Percent-based

1
2.5 %
**Land use mix measurement**

**Pattern**
Level of integration among different land use types in an area

**Theorized link to travel**
Mix of residential and nonresidential land uses encourages internal walking trips in place of potential external auto trips

**Shortcomings**
- Entropy indices have perfect balance assumption
- Limited consideration of functional complementarity
- Concentration on non-spatial composition measures
- Variety in adoption of land use typologies

**Pattern Measures**

- **Composition**
  - Entropy
  - 0.73

- **Configuration**
  - ???
Land use composition and configuration

- Composition:
  - Simple
  - Complex

- Configuration:
  - Simple
  - Complex

Legend:
- Land Use Type I
- Land Use Type II
- Land Use Type III
- Land Use Type IV
Pattern in landscape ecology research

- Richness
- Proportion
- Diversity
- Evenness

- Patch Size / Shape
- Isolation / Proximity
- Contagion / Interspersion
- Connectivity

Land Use Pattern

Composition

Configuration
Study objectives

1. Introduce land use mix measure reflecting construct’s multidimensionality
   • Quantify the composition, configuration, and complementarity of local land use types
   • Explore the impact of geographic scale on land use mix measurement

2. Demonstrate connection between mix construct and pedestrian travel
   • Examine impact of mix on trip-level walk mode choice and home-based walk frequency
   • Compare effect of land use mix construct to effect of entropy and other BE measures
Study area & data sources

Land use
- Parcel-level data from local jurisdictions
  - Study area contained 904,398 parcels
  - Disaggregated to 65,312,000 66-ft grid cells
- Additional data from secondary sources
  - Density: 2010 US Census and 2011 LEHD
  - Design: 2011 TIGER files

Transportation
- 2009-11 OR Household Travel and Activity Survey
  - Info on 8,725 households, 14,264 adults, & 64,060 trips
  - Walking feasible (≤ 2 miles) for 29,198 trips
  - Walk mode chosen for 15% of trips (n = 4,344)
Analytic plan

Land Use Mix Measurement
- APA Land-based Classification Standards (Function)
- Operationalize indicators at artificial fixed grids
  - 1.00-mile grid: 10,250 cells
  - 0.50-mile grid: 40,820 cells
  - 0.25-mile grid: 163,280 cells
- Confirmatory Factor Analysis
- Assign predicted factor scores to grid cells

Connection to Pedestrian Travel
- Estimate impact of mix on walk mode and trip count
- Compare land use mix construct to entropy index and other BE determinants of walking behaviors
Land Use Mix Measurement

- **Residential and Retail Patch Richness**
  - \( \lambda \) Range: 0.62 to 0.67

- **Activity-related Complementarity**
  - \( \lambda \) Range: 0.85 to 0.89

- **Maximum Patch Size**
  - \( \lambda \) Range: -0.92 to -0.92

- **Contagion Index**
  - \( \lambda \) Range: -0.96 to -0.96

CFA Model Summaries

- **M1: Quarter-Mile Grids**
  - CFI: 0.99
  - RMSEA: 0.02

- **M2: Half-Mile Grids**
  - CFI: 0.99
  - RMSEA: 0.06

- **M3: One Mile Grids**
  - CFI: 0.99
  - RMSEA: 0.09
Land use mix construct

0 - 1 SD

+ 3 SD

2 - 3 SD

1 - 2 SD
Connection to Pedestrian Travel

**Pedestrian Travel**

**Individual & Household Factors**
- Age
- Education
- Gender
- Household children
- Household income
- Household vehicles

**Built Environment Factors**
- Population density
- Employment density
- City block centroids
- Connected node ratio
- Land use entropy
- Land use mix construct

**Other Contextual Factors**
- Trip distance
## Walk Mode Choice

### Decision to Walk

- **Age**
- **Education**
- **Female**
- **Household children**
- **Household income**
- **Household vehicles**
- **Trip distance**
- **Land use entropy**
- **Land use mix construct**

### Table

<table>
<thead>
<tr>
<th></th>
<th>0.25 mile</th>
<th>0.50 mile</th>
<th>1.00 mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Education</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Female</td>
<td>--</td>
<td>--</td>
<td>--</td>
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<tr>
<td>Household children</td>
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<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Household income</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Household vehicles</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Trip distance</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Land use entropy</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Land use mix construct</td>
<td>+</td>
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<td>+</td>
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</tbody>
</table>

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**Note:** The symbols “+” and “--” represent positive and negative relationships, respectively, with the mode choice. "NS" indicates no significant relationship.
## Walk Trip Frequency

**Number of Home-based Walk Trips**

<table>
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<tbody>
<tr>
<td>Education</td>
<td>--</td>
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</tr>
<tr>
<td>Household children</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Household vehicles</td>
<td>--</td>
<td>--</td>
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</tr>
<tr>
<td>Population density</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Employment density</td>
<td>NS</td>
<td>NS</td>
<td>+</td>
</tr>
<tr>
<td>City block centroids</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Connected node ratio</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Land use mix construct</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

*Age, household income, and gender were not statistically significant*
Conclusions

Study Findings

- Improved land use mix measurement
  - Multidimensional construct described by intensity, composition, and configuration
  - Activity-related complementarity indicator moves beyond equal balance assumption
- Demonstrated link to pedestrian travel
  - Construct was stronger predictor of decision to walk than entropy measure
  - Construct was also significant predictor of home-based walk trip frequency

Next Steps

- SEM framework for retention of construct in measurement model
- Further attention to choice of geographic scale used to operationalize construct
- Transferability to states with weaker growth management policies
Thank you. Questions?

Steven R. Gehrke (sgehrke@pdx.edu)
Civil & Environmental Engineering
Portland State University
**Activity-related Complementarity**

Pattern Measure of Land Use Composition

\[ ARC = 1 - \sum_{i=1}^{n} \left[ P_i \cdot \frac{|P_i - F_i|}{1 - F_i} \right] \]

Where,

- \( P_i \) = Proportion of Land Use Type \( i \)
- \( F_i \) = Activity Factor for Land Use Type \( i \)

<table>
<thead>
<tr>
<th>Land Use Type</th>
<th>1000: Residence</th>
<th>2000: Sales</th>
<th>3000: Trade</th>
<th>4000: Transport</th>
<th>5000: Entertain</th>
<th>6000: Education</th>
<th>7000: Construct</th>
<th>8000: Extraction</th>
<th>9000: Agriculture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity Factor</td>
<td>0.41</td>
<td>0.31</td>
<td>0.03</td>
<td>0.01</td>
<td>0.01</td>
<td>0.17</td>
<td>0.00</td>
<td>0.00</td>
<td>0.06</td>
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</tbody>
</table>