Development of a Pedestrian Demand Estimation Tool

Framework and Methods

Kelly J Clifton, PhD
Outline

• Background
• Project, methods, zones, & data
• Pedestrian index of the environment (PIE)
• I: Trip generation
• II: Walk mode split
• III: Pedestrian destination choice
• Conclusions & future work

Adapted from: http://www.flickr.com/photos/takomabibelot/3223617185
BACKGROUND
Why model pedestrian travel?

- plan for pedestrian investments & non-motorized facilities
- mode shifts
- greenhouse gas emissions
- health & safety
- new data
Background

How do travel models estimate walking?

• Among 48 large MPOs in US:
  – 38% did not estimate walking
  – 33% estimated non-motorized (walking + bicycling) travel
  – 29% estimated walking

• Lacking pedestrian built environment measures & small spatial units

What are some opportunities?

- **Walking behavior data**
  - improved travel surveys, pedestrian count data collection

- **Built environment data**
  - archived spatial datasets, GIS processing

- **Travel demand models**
  - smaller zones, complete networks, computer power

- **Walking behavior research**
  - more knowledge and studies
PROJECT, METHODS, ZONES & DATA
Project overview

• Partnered with Metro: metropolitan planning organization for Portland, OR
• Two research projects
• Improve representation of pedestrian environment in current 4-step method
Current 4-step method

TAZ = transportation analysis zone

Trip Generation (TAZ)

Trip Distribution or Destination Choice (TAZ)

Mode Choice (TAZ)

Trip Assignment

Pedestrian Trips

All Trips  Pedestrian Trips  Vehicular Trips

Background – Project – PIE – Walk Model – DC Model – Conclusion
New MoPeD method

- Trip Generation (PAZ)
- Walk Mode Split (PAZ)
- Destination Choice (PAZ)
- Pedestrian Trips
- Trip Distribution or Destination Choice (TAZ)
- Mode Choice (TAZ)
- Trip Assignment

TAZ = transportation analysis zone
PAZ = pedestrian analysis zone

Background – Project – PIE – Walk Model – DC Model – Conclusion
MoPeD Contributions

Operates at a smaller spatial scale, more relevant to pedestrians (PAZ)

Utilizes spatially fine-grained archived information on the built environment

Incorporates knowledge of influences on pedestrian travel behavior

Designed to work with regional travel demand model or as standalone tool
Pedestrian analysis zones

264 feet ≈ 80 m ≈ 1 minute walk

Metro: ~2,000 TAZs ➔ ~1.5 million PAZs
Travel survey data

• Oregon Household Activity Survey (OHAS)
  – Household-based survey
  – One-day travel diary
• Portland region dataset (2011)
  – 6,100 households
  – 13,400 people
  – 56,000 trips ÷ 4,500 walk trips
    ≈ 8% walk mode share
PEDESTRIAN INDEX OF THE ENVIRONMENT (PIE)
Pedestrian environment

Pedestrian Index of the Environment (PIE)

20–100 score = calibrated $\sum$ (6 dimensions)

ULI = Urban Living Infrastructure: pedestrian-friendly shopping and service destinations used in daily life.
Visualizing PIE

100 – Downtown core

80 – Major neighborhood centers

Background – Project – PIE – Walk Model – DC Model – Conclusion
Visualizing PIE

70 – Suburban downtowns

60 – Residential inner-city neighborhoods
Visualizing PIE

50 – Suburban shopping malls

40 – Suburban neighborhoods/subdivisions
Visualizing PIE

30 – Isolated business and light industry

20 – Rural, undeveloped, forested
I. TRIP GENERATION
Trip Generation (PAZ)

Walk Mode Split (PAZ)

Destination Choice (PAZ)

Pedestrian Trips

Trip Distribution or Destination Choice (TAZ)

Mode Choice (TAZ)

Trip Assignment

TAZ = transportation analysis zone
PAZ = pedestrian analysis zone
Trip Generation

Metro currently has 8 trip production models applied to ~2,000 TAZs:

- HBW – Home-based work;
- HBshop – Home-based shopping;
- HBrec – Home-based recreation;
- HBoth – Home-based other (excludes school and college);
- NHBW – Non-home-based work;
- NHBNW – Non-home-based non-work;
- HBcoll – Home-based college; and
- HBsch – Home-based school.

After testing for scalability, we applied the same models to our pedestrian scale ~1.5M PAZs.
II. WALK MODE SPLIT
Walk mode split

1. Trip Generation (PAZ)
2. Walk Mode Split (PAZ)
3. Destination Choice (PAZ)

TAZ = transportation analysis zone
PAZ = pedestrian analysis zone

- Trip Distribution or Destination Choice (TAZ)
- Mode Choice (TAZ)
- Trip Assignment

Pedestrian Trips

All Trips  Pedestrian Trips  Vehicular Trips

Background – Project – PIE – Walk Model – DC Model – Conclusion
Walk mode split

\[ \text{Prob}(\text{walk}) = f(\text{traveler characteristics, PIE}) \]

**Data:** 2011 OHAS, Production trip ends, 90% sample

**Method:** binary logit model

**Spatial unit:** pedestrian analysis zone (PAZ)
Walk mode split models

Traveler characteristics: Household size, income, age, # of workers, # children, # vehicles

Built environment: PIE
Traveler characteristics:

+ positively related to walking
  - number of children in HH

– negatively related to walking
  - age of household head
  - HH vehicle ownership

Ped. Environment:

+ 10 points PIE

Δ odds of choosing to walk

43% increase (HBW)
54% increase (HBNW)
67% increase (NHB)

Pseudo $R^2$

0.137 (HBNW) – 0.253 (NHB)
Mode Split Validation

1. Apply the final model equations to trips in the validation sample (10% of data) and calculate the walk probability for each trip;

2. Average the probabilities to get the predicted walk mode share of trip ends (called sample enumeration)

<table>
<thead>
<tr>
<th>Model</th>
<th>HBW</th>
<th>HBO</th>
<th>NHB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed Walk Mode Share</td>
<td>2.9%</td>
<td>9.4%</td>
<td>6.7%</td>
</tr>
<tr>
<td>Predicted Walk Mode Share</td>
<td>3.0%</td>
<td>9.5%</td>
<td>8.6%</td>
</tr>
</tbody>
</table>
Walk model application
Walk mode split

1. Trip Generation (PAZ)
2. Walk Mode Split (PAZ)
3. Destination Choice (PAZ)

Pedestrian Trips

TAZ = transportation analysis zone
PAZ = pedestrian analysis zone

Trip Distribution or Destination Choice (TAZ)
Mode Choice (TAZ)
Trip Assignment

All Trips
Pedestrian Trips
Vehicular Trips
III. DESTINATION CHOICE
Destination choice

1. Trip Generation (PAZ)
2. Walk Mode Split (PAZ)
3. Destination Choice (PAZ)

- Trip Distribution or Destination Choice (TAZ)
- Mode Choice (TAZ)
- Trip Assignment

TAZ = transportation analysis zone
PAZ = pedestrian analysis zone

- All Trips
- Pedestrian Trips
- Vehicular Trips

Background – Project – PIE – Walk Model – DC Model – Conclusion
**Destination choice**

\[ \text{Prob(dest.)} = \text{function of…} \]

- network distance
- size / # of destinations
- pedestrian environment
- traveler characteristics

**Data:** 2011 OHAS

**Method:** multinomial logit model

**Spatial unit:** super-pedestrian analysis zone

**Six trip types:**
- **home-based:** work (HBW), shopping (HBS), recreation (HBR), & other (HBO);
- **non-home-based:** work (NHBW) and non-work (NHBNW)
Destination choice

1. Aggregate PAZs to superPAZs
2. Apply destination choice model
3. Allocate trips from each superPAZ to PAZs
Destination Choice

superPAZ:
- a grid of $5 \times 5 = 25$ PAZs

Choice set generation:
- Random sample of 10 superPAZs within 3 miles
- 99% of OHAS walk trips < 3 miles (4.8 km)
Destination Choice

Key variables

- Impedance
  - network distance btw. zones

- Size
  - employment by category, households

Additional variables

- Pedestrian supports
  - PIE, parks

- Pedestrian barriers
  - slope, freeway, industrial LUs

- Traveler attributes
  - auto own., children
Impedance

+ 1 mile of distance
  by auto own.: 76–86% decrease (*)
  by children: -62% (no), -74% (yes) (HBW)
  by children: -78% (no), -83% (yes) (HBR)
  by children: -78% (no), -90% (yes) (HBS)

Size

2 × # destinations
  minimum: 28–42% increase (†)
  maximum: 4% increase (HBR)
  88% increase (HBS)

* Except for HBW, HBR, and HBS.
† Except for HBR and HBS.
Destination Choice

<table>
<thead>
<tr>
<th>Ped. supports</th>
<th>Δ odds of walking to destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 10 points PIE: PIE</td>
<td>16–34% increase (*)</td>
</tr>
<tr>
<td>presence of park:</td>
<td>58% increase (HBR)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ped. Barriers</th>
<th>Δ odds of walking to destination</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ 1° mean slope:</td>
<td>14–35% decrease (2,3,4)</td>
</tr>
<tr>
<td>presence of freeway:</td>
<td>64% decrease (2)</td>
</tr>
<tr>
<td>+ 1% industrial jobs:</td>
<td>33–82% decrease (1,2,3,4)</td>
</tr>
</tbody>
</table>

Pseudo R²

0.416 (HBR) – 0.680 (HBS)

* Except for HBS and HBR.

1 HBW, 2 HBS, 3 HBO, 4 NHBW.
### Destination Choice

#### Background – Project – PIE – Walk Model – DC Model – Conclusion

#### Doubling size is equivalent to...

<table>
<thead>
<tr>
<th>Category</th>
<th>Reduction (X miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBW (1+ auto households)</td>
<td>0.26</td>
</tr>
<tr>
<td>HBW (0 auto households)</td>
<td>0.37</td>
</tr>
<tr>
<td>HBS (1+ child households)</td>
<td>0.28</td>
</tr>
<tr>
<td>HBS (0 child households)</td>
<td>0.41</td>
</tr>
<tr>
<td>HBR (1+ child households)</td>
<td>0.02</td>
</tr>
<tr>
<td>HBR (0 child households)</td>
<td>0.02</td>
</tr>
<tr>
<td>HBO</td>
<td>0.14</td>
</tr>
<tr>
<td>NHBW</td>
<td>0.18</td>
</tr>
<tr>
<td>NHBNW</td>
<td>0.19</td>
</tr>
</tbody>
</table>

...reducing a one-mile walk trip by X miles
Model Validation – % Correct Destination

- HBW: 54%
- HBS: 75%
- HBR: 38%
- HBO: 53%
- NHBW: 55%
- NHBNW: 53%

Percentage of cases, modeled destination = correct destination
Model Validation – Avg. Distance Walked

HBW: 0.55
HBS: 0.57
HBR: 0.53
HBO: 0.51
NHBW: 0.38
NHBNW: 0.41

Distance walked, mean, in miles

Correct
Modeled
CONCLUSIONS & FUTURE WORK
Conclusions

• Nests within current model but can be used alone
• Pedestrian scale analysis (PAZs)
• Pedestrian-relevant variables (PIE)
• One of the first studies to examine pedestrian destination choice in modeling framework
• Highlights policy relevant variables: distance, size, pedestrian supports & barriers
Future work

Before application:

• Relate PIE more explicitly to policy changes
• Forecasting inputs
• Test method in other area(s)/regions
  – Examine relationships in other contexts
  – Assess PIE’s transferability
• Provide agency guidance for implementation
Future work

Research & Model Improvements:

Trip Generation
  – Multinomial Logit model

• Destination Choice
  – Allocate from superPAZ to PAZ level
  – Explore non-linear effects & other interactions

• Route choices or potential pathways
  – Need fundamental research to improve understanding
Questions?

Project info & reports:
http://trec.pdx.edu/research/project/510
http://trec.pdx.edu/research/project/677

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