Introduction to Activity-Based Demand Modeling

Tennessee Model Users Group
November 16, 2012
Topics

- Trip-based models
  - Review
  - Advantages/Criticisms
- Activity-based models
  - Introduction
  - Model Components
  - Implementation
  - Outputs
  - Advantages/Criticisms
- Discussion
Trip-Based Models

- Trip Generation
  - How many trips from/to an area
- Trip Distribution
  - Links trips into flows or trip tables
- Trip Mode Choice
  - Splits trip tables into trips by mode
- Trip Time-of-Day Factors
  - Split trips by time-of-day and direction
- Trip Assignment
  - Assigns routes to trips
Trip-Based Models

Production & Attraction Table

<table>
<thead>
<tr>
<th>Zone</th>
<th>Home-Based Work (HBW)</th>
<th>Home-Based Other (HBO)</th>
<th>Non-Home-Based (NHB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
## Trip-Based Models

### Trip Generation

<table>
<thead>
<tr>
<th>Zone</th>
<th>( P_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>2</td>
<td>66</td>
</tr>
</tbody>
</table>

### Trip Attractions (\( A_j \))

<table>
<thead>
<tr>
<th>Zone</th>
<th>( A_j )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>82</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
</tr>
</tbody>
</table>

### Trip Distribution

<table>
<thead>
<tr>
<th>From Zone</th>
<th>To Zone</th>
<th>1</th>
<th>2</th>
<th>Total ( P_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27</td>
<td>7</td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>2</td>
<td>55</td>
<td>11</td>
<td></td>
<td>66</td>
</tr>
<tr>
<td>Total ( A_j )</td>
<td>82</td>
<td>18</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

### Mode Choice

<table>
<thead>
<tr>
<th>Mode</th>
<th>Trips ( Tijm )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>30</td>
</tr>
<tr>
<td>Transit</td>
<td>25</td>
</tr>
</tbody>
</table>

### Trip Assignment

<table>
<thead>
<tr>
<th>Route</th>
<th>Trips ( Tijmr )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route A</td>
<td>18</td>
</tr>
<tr>
<td>Route B</td>
<td>7</td>
</tr>
</tbody>
</table>
Some Advantages of Trip-Based Models

- **Aggregate**
  - Good for aggregate analysis of changes in land use and their impact on the transportation system (such as changes in roadway level-of-service)

- **No randomness**
  - Same model results every time and models the average

- **Not as much data and time required to develop**
  - Faster and easier to develop as compared with the next-generation ABMs

- **Run faster than ABMs**

- **Standard practice at most MPOs and DOTs today**
  - Highway project analysis
  - Transit project analysis
Some Criticisms of Trip-Based Models

- Lack of Behavioral Fidelity
  - Use static rates/factors such as trip generation rates
  - The only model based on decision-making theory is mode choice

- Aggregation Bias
  - No information on non-home-based trips
  - Temporal, spatial, socio-economic
  - Computational challenges of adding markets

- Lack of Policy Responsiveness
  - Time-of-day shifts
  - Accessibility
  - Land-use interactions
Limitations of Trip-Based Models: Examples

- **Scenario #1:** Add capacity to the network
  - Problem: There are no time-of-day shifts in the model since it uses static factors so ~10% of travel is in the PM peak regardless of the network capacity

- **Scenario #2:** Operational differences between managed lane in AM peak period/direction versus PM peak period/direction.
  - Problem: Demand is only sensitive to AM level-of-service (LOS). No connection between outbound trips to work in the AM and return trips back home in the PM

- **Scenario #3:** Planners want equity analysis for low-income households, single-parent households, etc.
  - Problem: Auto ownership is the only household attribute available
What is an Activity-Based Travel Model?

- Travel is a **derived demand** – it results from the need for people to engage in activities outside the home.
- Activity-based travel models attempt to replicate how **people** decide:
  - whether to travel
  - where to travel to
  - when to travel
  - how to travel
- Activity-based travel models are based on **behavioral decision-making theory**
- This makes them more suited to address policies that affect how people make travel decisions than trip-based models.
Activity-Based Travel Model Themes

- Model travel by **individuals**
  - Important socio-economic characteristics are tracked explicitly
  - Micro-simulation used (i.e. every person modeled)

- Model trips as part of **tours**
  - A series of trips beginning and ending at home or work (anchor locations)
  - Primary destination, intermediate stops
  - No more stand-alone non-home-based trips that were very difficult to model in a four-step model

- Schedule activities consistently in **time and space**
  - Activities occur in available time windows
  - No person can be in two places at the same time
Some Sensitivities of ABMs

- Effects of transport policies on time-use
- Demographic changes & equity analysis
- Demand management policies (parking, HOV, pricing)
- Changes in accessibilities
- Better interface with traffic simulation models such as Dynamic Traffic Assignment (DTA)
- Telecommuting
- Evacuation planning
- Household level VMT and GHG
ABM Model Steps

Synthetic Population

Mobility Choices

Trip Details

Model Outputs

Long-Term Choices

Daily Activity Pattern and Tours

Trip Assignment

Model Inputs

Network level-of-service and accessibilities

Synthetic travel diary for everyone!
Synthetic Population

- Obtain a sample of households and persons from Census PUMS records for region
- Generate a synthetic population of households and persons to match input control targets (such as # of households by size and income by TAZ)
Person Types

- ABMs model person types as opposed to household market segments
- Person types can be used to segment models and as explanatory variables

<table>
<thead>
<tr>
<th>ID</th>
<th>PERSON-TYPE</th>
<th>AGE</th>
<th>WORK STATUS</th>
<th>SCHOOL STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Full-time worker</td>
<td>18+</td>
<td>Full-time</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Part-time worker</td>
<td>18+</td>
<td>Part-time</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>Non-working adult</td>
<td>18 – 64</td>
<td>Unemployed</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>Non-working senior</td>
<td>65+</td>
<td>Unemployed</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>College student</td>
<td>18+</td>
<td>Any</td>
<td>College +</td>
</tr>
<tr>
<td>6</td>
<td>Driving age student</td>
<td>16-17</td>
<td>Any</td>
<td>Pre-college</td>
</tr>
<tr>
<td>7</td>
<td>Non-driving student</td>
<td>6 – 16</td>
<td>None</td>
<td>Pre-college</td>
</tr>
<tr>
<td>8</td>
<td>Pre-school</td>
<td>0-5</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>
Activity Purposes

- Mandatory activities
  - Work, School, University
  - Least flexible in terms of generation, scheduling
  - Foundation of daily activity pattern for workers & students

- Maintenance activities
  - Escort, Shop, Other Maintenance
  - Activities performed on behalf of household

- Discretionary activities
  - Eating out, Social/recreation, Other Discretionary
  - Most flexible in terms of generation, scheduling
ABM Tours and Trips

Data View:

<table>
<thead>
<tr>
<th>HH #</th>
<th>Per #</th>
<th>Tour #</th>
<th>Purp</th>
<th>Origin TAZ</th>
<th>Destin. TAZ</th>
<th>Outbound Stop1 TAZ</th>
<th>Return Stop1 TAZ</th>
<th>Mode</th>
<th>Sub-tour</th>
<th>Sub-Tour Destin.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1023</td>
<td>1</td>
<td>1</td>
<td>Work</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>2</td>
<td>Transit</td>
<td>Yes</td>
<td>4</td>
</tr>
</tbody>
</table>
Bus to Work = Drive alone not available for lunch
ABM Individual and Joint Travel

- **Partially joint travel:** Person 1 (worker) escorts person 2 (student) to school

- **Fully joint travel:** Person 1 (worker) and person 2 (student) both go to dinner and return together
Treatment of Time

- Different temporal systems used
  - 5 time periods, hourly, half-hourly, continuous

- Use aggregate time periods for network LOS indicators and disaggregate time periods for activity scheduling
  - Example: 5 periods for network LOS indicators, half-hourly periods for scheduling activities

<table>
<thead>
<tr>
<th>Continuous Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 A.M.</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Half-Hourly Periods</td>
</tr>
<tr>
<td>Hourly Periods</td>
</tr>
<tr>
<td>Early AM</td>
</tr>
</tbody>
</table>
Example of Activity Scheduling

1. Schedule Work Tour
   - < 7:30
   - 7:30 A.M. – 5:00 P.M.

2. Calculate residual time windows

3. Schedule Discretionary Tour
   - 7 – 9 P.M.
Treatment of Space: TAZs and MAZs (micro-zones)

- Different spatial systems can be used in ABMs
  - TAZs used in trip-based model can also be used in ABM
  - More detailed spatial units (MAZs, parcels) can also be used
    - Network impedances for non-motorized travel (walk, bike, walk to transit) at the MAZ level
    - SANDAG: 4,605 TAZs (orange) and 33K MAZs (grey)
Treatment of Space: Parcels

- Uses TAZ-TAZ travel times for auto and transit in-vehicle time, wait time, cost, etc
- Replaces network walk time to transit with walk time from parcel to nearest stop via straight-line distance
- Uses parcel-parcel walk/bike time via straight-line distance for nearby parcels, zone-zone distance for further away parcels
Multiple Levels of Network Impedance

- In addition to TAZs and MAZs, can also use TAPs (transit access points)
- TAPs are (aggregate) transit demand virtual zones
- Resulting network impedances:
  - Auto: TAZ to TAZ
  - Transit Line Haul: TAP to TAP
  - Walk, Bike, Walk to Transit: MAZ to MAZ
  - All travel modeled at the MAZ level, but use an appropriate spatial precision for the mode
  - No more transit access/egress issues since that is handled by the demand modeling software now
Model Implementation Framework

Trip-Based Models

- One set of calculations *per cell*
- Each market segment = new set of trip tables
- More markets = more calculations

Micro-simulation

- One set of calculations *per agent*
- Each market segment = new column
- More markets = no more calculations
- Databases instead of matrices

```
<table>
<thead>
<tr>
<th>HID</th>
<th>PID</th>
<th>AUT</th>
<th>INC</th>
<th>WRK</th>
<th>GEN</th>
<th>AGE</th>
<th>EMP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>24</td>
<td>1</td>
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<td>1</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
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<td>0</td>
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<td>2</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>32</td>
<td>1</td>
</tr>
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<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>34</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>49</td>
<td>1</td>
</tr>
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<td>3</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>47</td>
<td>1</td>
</tr>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>1</td>
</tr>
</tbody>
</table>
```
ABM Monte Carlo Simulation Example

<table>
<thead>
<tr>
<th>Autos</th>
<th>Utility</th>
<th>Exp(Utility)</th>
<th>Probability</th>
<th>Cumulative Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1.0000</td>
<td>0.0570</td>
<td>0.0570</td>
</tr>
<tr>
<td>1</td>
<td>1.7</td>
<td>5.4739</td>
<td>0.3122</td>
<td>0.3692</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>7.3891</td>
<td>0.4215</td>
<td>0.7907</td>
</tr>
<tr>
<td>3+</td>
<td>1.3</td>
<td>3.6693</td>
<td>0.2093</td>
<td>1.0000</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>17.5323</td>
<td>1.0000</td>
<td></td>
</tr>
</tbody>
</table>

Random Number Draw = 0.3897
= 2 autos
Advantages and Disadvantages of Simulation

**Advantage**
- Computational efficiency
  - Full availability of all variables
  - Outcomes of previous model components can be used as explanatory variables in subsequent components
- Provides distribution of results as opposed to one number

**Disadvantage**
- Requires multiple runs in order to obtain expected values
- Use of the same model and same inputs but different random seed yields different results

**Approaches to manage the variability**
- Average multiple runs for example
### Transparent Choice Model Specifications

**A row for each utility term**

<table>
<thead>
<tr>
<th>Model</th>
<th>auto_ownership</th>
<th>Decision-making-unit</th>
<th>h</th>
<th>Alt1</th>
<th>Alt2</th>
<th>Alt3</th>
<th>Alt4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Token</td>
<td>Description</td>
<td>Filler</td>
<td>Formula for variable</td>
<td>Index</td>
<td>0_auto</td>
<td>1_auto</td>
</tr>
<tr>
<td>1</td>
<td>Alternative-specific constant</td>
<td>1</td>
<td></td>
<td></td>
<td>-0.352</td>
<td>-2.132</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Household Size 1</td>
<td>if(@size==1,1,0)</td>
<td></td>
<td></td>
<td>2.613</td>
<td>2.172</td>
<td>0.0</td>
</tr>
<tr>
<td>3</td>
<td>Household Size 2</td>
<td>if(@size==2,1,0)</td>
<td></td>
<td></td>
<td>0.000</td>
<td>0.400</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>Income Group 1</td>
<td>if(@income==1,1,0)</td>
<td></td>
<td></td>
<td>2.878</td>
<td>2.185</td>
<td>0.0</td>
</tr>
<tr>
<td>5</td>
<td>Income Group 2</td>
<td>if(@income==2,1,0)</td>
<td></td>
<td></td>
<td>1.734</td>
<td>1.731</td>
<td>0.0</td>
</tr>
<tr>
<td>6</td>
<td>Income Group 3</td>
<td>if(@income==3,1,0)</td>
<td></td>
<td></td>
<td>0.000</td>
<td>1.152</td>
<td>0.0</td>
</tr>
<tr>
<td>7</td>
<td>Income Group 4</td>
<td>if(@income==4,1,0)</td>
<td></td>
<td></td>
<td>0.000</td>
<td>0.669</td>
<td>0.0</td>
</tr>
<tr>
<td>8</td>
<td>Worker 0</td>
<td>if(@workers==0,1,0)</td>
<td></td>
<td></td>
<td>1.015</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>9</td>
<td>Worker 1</td>
<td>if(@workers==1,1,0)</td>
<td></td>
<td></td>
<td>0.000</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>10</td>
<td>Worker 2</td>
<td>if(@workers==2,1,0)</td>
<td></td>
<td></td>
<td>0.000</td>
<td>-0.534</td>
<td>0.0</td>
</tr>
<tr>
<td>11</td>
<td>Worker 3+</td>
<td>if(@workers==3,1,0)</td>
<td></td>
<td></td>
<td>2.195</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>12</td>
<td>GVSAD retirement zone</td>
<td>if(GV_SAD_IND==1,1,0)</td>
<td>z</td>
<td></td>
<td>0.000</td>
<td>1.200</td>
<td>0.0</td>
</tr>
<tr>
<td>13</td>
<td>HRET retirement zone</td>
<td>if(HI_RET_IND==1,1,0)</td>
<td>z</td>
<td></td>
<td>0.000</td>
<td>0.016</td>
<td>0.0</td>
</tr>
<tr>
<td>14</td>
<td>Tot emp w/ 20 min by transit, normalized</td>
<td>trm20m_emp</td>
<td>z</td>
<td></td>
<td>0.014</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>15</td>
<td>Percent of TAZ w/ 1/3 mile of transit stop</td>
<td>shortWalk</td>
<td>z</td>
<td></td>
<td>0.021</td>
<td>0.010</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**A column for each alternative (0, 1, 2, and 3+ autos)**

**A description for the term**

**A formula field for computing data items**

**Coefficients for each term and alternative**

Utility Expression Calculator Example
Example ABM System Setup (ARC)

- Cube runs the model and calls ABM Java software.
- Both Cube and Java are distributed to take advantage of multiple computing cores since most sub-models can be parallelized by HH.
- Successfully running in the Cloud as well.
Activity/Tour Traces for Explaining/Debugging

Person id= 1018997 type= Full-time worker
Time Spent Travelling by Household Income and Person Type
ARC ABMVIZ Time Use

- New time use (person activity over the day)
- Can select different person types (the above is showing Full-time workers)
The above shows Part-time workers
Some Advantages and Criticisms of ABMs

- **Advantages**
  - More behavioral realism
  - More policy sensitivity to issues like equity, pricing, land use
  - More precise representations available
  - More consistent integration with dynamic traffic assignment
  - Flexible outputs for creating just about any type of data summary

- **Criticisms**
  - Introduction of variability/uncertainty to the model results (... maybe an advantage)
  - More data and time required to develop
  - More work to calibrate and validate
  - Slower run times

- **ABMs are being developed at a number of agencies across the country and are arguably the future of demand modeling**
Some Concluding Thoughts

- A shift in mindset from aggregate trips to individual persons is required (in terms of estimation, input data, implementation, outputs, etc)
- Just like trip-based models, each ABM is different
- The “right” model depends on the questions being asked
- More and more ABMs are being developed each year
- The ability of ABMs to better answer new and existing planning questions is exciting!
Discussion

- Ben Stabler, stabler@pbworld.com