The Transition to Activity Based Models: What, why, when, where, how?

presented to
Panel on Activity-Based Models

presented by
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May 26, 2010
What is different about activity-based models compared to typical four-step models?

- Units of decisions
  - Trips >> Tours >> Person-days >> Household-days >> Longer term choices

- Method of predicting choices
  - Top-down aggregate shares >> Bottom-up microsimulation

- Amount of detail that can be accommodated
  - Socio-Demographic: A few segmentations >> Many variables
  - Temporal: Broad time periods >> Hours or half-hours
  - Spatial: Zones >> Parcels or points

- It’s less familiar to most (current) potential users
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Using home-based tours as a second unit of behavior

Why?
- Mode, timing, destination of trips on a tour are highly related
- Current models do a poor job predicting NHB trips

When and where?
- Netherlands National and Regional Models (mid-1980’s)
- CS models in Idaho, New Hampshire (mid-1990’s)
- A feature of all ABM since (Portland, San Francisco, NYC, Columbus, Sacramento, Tahoe, Atlanta, Bay Area, Seattle, Denver, San Diego, Los Angeles, Phoenix, Jacksonville, …)

How?
- Original implementations were modified four-step
- Realistic treatment of intermediate destinations is only feasible in a microsimulation framework (Portland)
<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>1</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>2</td>
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<td></td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1</td>
<td>1</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>
ABM: Tours and Trips

Home-Based Work Trip

Zone 1
Origin
Home-Based Other Trip

Intermediate Stop
Zone 2

Work Tour

Primary Destination
Non-Home-Based Trip
Zone 3

Work-Based Tour
Primary Destination
Non-Home-Based Trip
Zone 4

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>
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</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>
Activity-Based Models: Mode Consistency

Work Tour:
- Zone 1
- Zone 2
- Zone 3

Work-Based Tour:
- Zone 3
- Zone 4

Bus to Work = Drive alone not available for lunch
Using person-days as a third unit of behavior

Why?
- Tours in a day are related because of time-space constraints
  - substitution among tours
  - substitution between more trips on tours versus more tours
  - affected by travel conditions
- Model time of day choices realistically

When and where?
- Boston (Bowman and Ben Akiva, mid-1990’s)
- Portland, San Francisco implementations (late 1990’s)
- A feature of all ABM since (but with various assumptions)

How?
- Requires another level of choice hierarchy in microsimulation frameworks, plus good travel diary data.
Time-Use Concept: Scheduling of Tours in a Day

Recalculate residual time windows

5-6 1-Work 18-19 2-Discret
7-17
20-23

5 23
Modeling explicit linkages between household member’s activity and travel patterns

Why?
- Explicit interactions between household members (e.g. parents taking kids to school)
- Joint travel has different constraints, policy sensitivities

When and where?
- Joint discretionary tours: Columbus (Vovsha, mid 2000’s)
- Joint work/school half-tours: San Diego, Seattle (2010?)
- Will be a feature of all ABM soon

How?
- Requires yet another level of choice hierarchy in microsimulation frameworks, plus even better travel diary data
Modeling some decisions as “longer term” choices

**Why?**
- Choice of regular workplace, school, auto ownership are not day-to-day decisions, and can influence / be influenced by a wide variety of other related travel choices

**When and where?**
- San Francisco (late-1990’s)
- A feature of nearly all ABM since
- Newest ABM’s may include a wider range (transit pass holding, usual work schedule, usual mode to work)

**How?**
- Fit naturally into the structure of AB microsimulation models to loop across individual households and persons.
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Top-down forecasting (aggregate four step)  
Multiplying rates and fractions

- **Households** by population segment / residence TAZ
  < Trip generation rates >
- **Trips** by population segment / trip purpose / residence TAZ
  < Trip distribution model >
- Trips by pop. segment / trip purpose / O-D TAZ pair
  < Time of day factors or model >
- Trips by segment / trip purpose / O-D pair / time period
  < Mode choice model >
- Trips by segment / trip purpose / O-D pair / time period / mode
  < = >
- **Many millions of numbers**, mostly small fractions of trips
Bottom-up forecasting (population microsimulation)  
Adding up discrete choices

• Apply a hierarchical series of models to predict behavior at several different levels for each representative household and person in the regional population:
  - Work and school locations
  - Auto ownership
  - Household-days
  - Person-days
  - Tours
  - Trips
    ♦ Origin and destination locations
    ♦ Departure time and arrival time
    ♦ Mode used

< = >

• **Millions of trip records**, each a single trip >> ADD THEM UP
## Monte Carlo Simulation Example – Auto Ownership

<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>
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<tr>
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<td>2</td>
<td>7.3891</td>
<td>0.4215</td>
<td>0.7907</td>
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<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

Cumulative Probability

- 0 Autos: 0.0570
- 1 Autos: 0.3692
- 2 Autos: 0.7907
- 3+ Autos: 1.0000

Random Number Draw = 0.3897

> 0.3897?
Tour-Based Model Output

Household Data, Person Data, Tour/Trip List

<table>
<thead>
<tr>
<th>HID</th>
<th>PID</th>
<th>TID</th>
<th>PUR</th>
<th>MOD</th>
<th>SB</th>
<th>SA</th>
<th>OTA</th>
<th>DNAZ</th>
<th>STAZ</th>
<th>S2TAZ</th>
<th>TLOR</th>
<th>TLDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>943</td>
<td>987</td>
<td>0</td>
<td>964</td>
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<td>943</td>
<td>565</td>
<td>698</td>
<td>982</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Maps, Graphics

Trip Tables

Assignment

Other Summaries
Trip-Based Model System

**URBAN FORECASTING AND PLANNING**

- Transport Networks
- Zonal Attributes
- Population Attributes
- Accessibility

**TRANSPORT MODEL SYSTEM**

- Resident trips
  - generation
  - distribution
  - mode split
- Other trips
  - airport
  - externals
  - commercial

- OD Matrices
- Static assignment
- Network performance (skims)
AB Model System with Static Assignment
AB Model System with Dynamic Assignment

Urban Forecasting and Planning

Transport Networks
Parcel and Zonal Attributes
Population Attributes
Accessibility

AB Household Travel Demand Simulator

Population and Long Term Choice Simulator
Person Day Simulator
HH/Person day-tour-trip list
Other trips
--airport
--externals
--commercial
Trip Disaggregator

Trip List
Dynamic assignment
Network performance (skims)

Transport Model System
There are many AB model systems (and active projects) in the US with static assignment.
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Accommodating greater detail

How (in general)?

- Population-based microsimulation procedures loop on individual households, persons, tours and trips
- They do NOT loop on combinations of zones/zone pairs, population segments, trip purposes, time of day periods
- So, run time depends mainly on the number of households, & is not very sensitive to the number of zones, time periods or population segments distinguished in the simulation.
- But, there may be costs in terms of generating and using related network and land use data...
Finer socio-demographic detail

Why?
- Research shows wide variation in behavior related to income, household composition, employment status, age, and other household and person characteristics
- Ignoring that variation leads to aggregation error and bias

When and where?
- All ABM implementations have used (various) procedures to generate synthetic, representative populations

How?
- Sample from PUMS / ACS records; control to Census data and available forecasts (HH size, HH income, HH workers).
- New methods are evolving; integration with land use models
Finer temporal detail

Why?
- Activity scheduling models need detail on available “time windows” for each activity
- Highway congestion can vary within short periods; departure time choice is more sensitive for small shifts

When and where?
- Continuous activity duration models (Bhat, Dallas, early 2000’s)
- Discrete scheduling models with shorter periods (Vovsha, Bradley, Columbus, mid-2000’s)
- A feature of all ABM since

How?
- Estimate and apply activity scheduling / duration models
- Traffic assignment / skims for more times of day (?)
SACSIM TOD validation versus survey
Work Tours by full-time workers
SACSIM TOD validation versus survey-Work Tours by part-time workers
Finer spatial detail

Why?

- Most TAZ systems are too sparse to adequately model
  - Effects of localized traffic congestion
  - Use of walk and bicycle modes and walk access to transit
  - Effects of changes in urban design and land use

When and where?

- Sacramento (SACSIM) implemented at parcel level (2005)
- Denver, Seattle, Jacksonville will be at parcel/point level
- San Diego uses very detailed subzones for transit access

How?

- Estimate and apply more detailed location choice models
- Methods to forecast parcel-level land use data
- Traffic assignment / skims for more network nodes(?)
FIGURE 4. SACMET (TAZ-to-TAZ) Measures of Travel Distance for Short Trips
FIGURE 3. SACSIM (Point-to-Point) Measures of Travel Distance for Short Trips
Non-Auto Mode Share versus Total Density at Place of Residence

Transit + Walk + Bike Mode Share

0.0% 5.0% 10.0% 15.0% 20.0% 25.0% 30.0% 35.0% 40.0% 45.0% 50.0%

<=4.0 4+ to 10 10+ to 20 20+ to 40 >40

Jobs /acre, dwellings /acre within 1/4 mile of residence

HH Survey
SACSIM
Daily VMT per Household versus Total Density at Place of Residence

Jobs/acre+ dwellings/acre within 1/4 mile of residence

- HH Survey
- SACSIM
Areas of Improvement: 2005 VMT / HH

Sacramento Area Council of Governments
Areas of Improvement: 2035 MTP VMT / HH

Roseville/Rocklin/Lincoln:
Red > Orange
Orange > Yellow
Yellow > Green

Sacramento Area Council of Governments
**Table 4. Summary Results from Model Sensitivity Tests**

<table>
<thead>
<tr>
<th>Test variable</th>
<th>Transit fare</th>
<th>Auto fuel cost</th>
<th>Highway capacity</th>
<th>Household income</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Response variable:</strong></td>
<td><strong>Elasticity</strong></td>
<td><strong>Elasticity</strong></td>
<td><strong>Elasticity</strong></td>
<td><strong>Elasticity</strong></td>
</tr>
<tr>
<td>Total person trips</td>
<td>-0.001</td>
<td>-0.010</td>
<td>+0.012</td>
<td>+0.119</td>
</tr>
<tr>
<td>Vehicle trips</td>
<td>+0.004</td>
<td>-0.036</td>
<td>+0.021</td>
<td>+0.151</td>
</tr>
<tr>
<td>Vehicle miles traveled</td>
<td>+0.006</td>
<td>-0.126</td>
<td>+0.144</td>
<td>+0.090</td>
</tr>
<tr>
<td>Transit trips</td>
<td>-0.226</td>
<td>0.151</td>
<td>-0.035</td>
<td>-0.415</td>
</tr>
<tr>
<td>Walk and bike trips</td>
<td>+0.005</td>
<td>0.067</td>
<td>-0.055</td>
<td>-0.091</td>
</tr>
</tbody>
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Potential issues in the transition to ABM (1)...

The models are more complicated and hard to understand
• Only to “veterans”; For students, ABM are more intuitive

The models are so complicated that they may not reflect behavior realistically
• Model components can be integrated via logsums

The methods are still evolving (a moving target)
• Recent applications evolving toward a common structure

The model results contain some random variation
• Can be minimized using multiple runs and random number synchronization across scenarios. Helps avoid false precision in interpreting results.
Potential issues in the transition to ABM (2)...

Can the models be used in the New Starts process?

- Yes (San Francisco, New York, Sacramento)

Requires software in addition to standard network packages

- The main software approaches are open source, and becoming more user-oriented over time

The models take longer to run

- Sometimes true, but much can be done with improved software and hardware (multi-processing, more memory)

Need to integrate travel demand models with other models

- It is already done now. In the future, ABM more “in synch” with the shift towards dynamic land use and traffic simulation models, with finer spatial and temporal resolution (SHRP 2 C10 project)