Travel Model of Future

Demonstration of Integrated Dynamic Policy Sensitive Model of Travel Demand for the Mega-Region of New York
Workshop Outline

- Dr. Peter Vovsha
  - Integration of advanced models of travel demand and network simulations as the main avenue in our profession

- Prof. Kay Ahxausen
  - MatSim platform and applications in Europe

- Dr. Michael Balmer
  - New York ABM – MatSim integration demonstration
Integrated Regional Travel Model

- Demand Model (4-step or ABM)
- Network simulations (UE or DTA)
“Putting a box around it, I’m afraid, does not make it a unified theory.”
Two Generations of Travel Demand Models

- 1\textsuperscript{st} generation: aggregate, trip-based, so-called 4-step models:
  - In practice since 1970\textsuperscript{th}
  - Still widely applied in the US, especially by smaller MPOs and transit agencies

- 2\textsuperscript{nd} generation: disaggregate, tour-based, so-called Activity-Based Models (ABMs):
  - In practice since early 2000\textsuperscript{th}
  - Prevailing practice for major MPOs in US
Two Generations of Regional Network Simulation Models

- **1st generation**: aggregate user equilibrium static assignments of traffic flows:
  - Based in pioneering work of Wardrop, 1952 and Beckman, 1956
  - In practice since 1970th as part of 4-step
  - Still widely applied in the US

- **2nd generation**: Dynamic Traffic Assignment (DTA) with individual-vehicle microsimulation:
  - Equilibrium formulation based in intensive research since 1990th
  - In practice since early 2000th for corridor-level studies
  - Individual vehicle microsimulation techniques borrowed from traffic microsimulation models
  - Meso-level techniques emerged from 2000th
# 4 Major Options

<table>
<thead>
<tr>
<th>Demand Model</th>
<th>UE</th>
<th>DTA</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-Step</td>
<td>1=Conventional well-explored</td>
<td>3=Usual for DTA in practice (demand is stretched)</td>
</tr>
<tr>
<td>ABM</td>
<td>2=Usual for ABM in practice (UE is stretched)</td>
<td>4=Most promising avenue (first attempts)</td>
</tr>
</tbody>
</table>
CONVENTIONAL INTEGRATION
SCHEMA 4-STEP WITH UE
Fundamentals – Origins

**UE – Beckmann, 1956**

$$\min_{\{x_{ijr}\}} \left\{ \sum_{a}^{v_{a}} \int_{0}^{c_{a}(w)} dw \right\}$$

Subject to:

$$\sum_{r} x_{ijr} = d_{ij}$$

$$v_{a} = \sum_{ijr} \delta_{ar} x_{ijr}$$

$$x_{ijr} \geq 0$$

Solution:

$$x_{ijr} \left( c_{ijr} - \min_{r} c_{ijr} \right) = 0$$

---

**Entropy max – Wilson, 1967**

$$\max_{\{y_{ij}\}} \left\{ - \sum_{ij} y_{ij} \ln y_{ij} \right\}$$

Subject to:

$$\sum_{j} y_{ij} = P_{i} \quad \sum_{i} y_{ij} = A_{j}$$

$$\sum_{ij} c_{ij} y_{ij} = C$$

$$y_{ij} > 0$$

Solution:

$$y_{ij} = P_{i} \alpha_{i} A_{j} \beta_{j} \exp\left(-\theta c_{ij}\right)$$

---

\(a=\text{links, } i=\text{origins, } j=\text{destinations, } r=\text{routes}\)
Combined UE & Trip Distribution, Evans, 1976

\[
\min_{\{x_{ijr}\}} \left\{ \sum_{a} v_a^a c_a(w) dw + \frac{1}{\theta} \sum_{ij} y_{ij} \ln y_{ij} \right\}
\]

Subject to:

\[
\sum_{r} x_{ijr} = y_{ij}
\]

\[
v_a = \sum_{ijr} \delta_{ar} x_{ijr}
\]

\[
x_{ijr} \geq 0
\]

Solution:

\[
x_{ijr} \left( c_{ijr} - \min_{r} c_{ijr} \right) = 0
\]

\[
y_{ij} = P_i \alpha_i A_j \beta_j \exp\left( -\theta \min_{r} c_{ijr} \right)
\]
Combined UE & Mode Choice, Florian et al, 1977

\[
\begin{align*}
\min_{\{x_{ijmr}\}} \left\{ \sum_{am} v_{am} \int c_{am}(w) dw + \frac{1}{\theta} \sum_{ijm} y_{ijm} \ln y_{ijm} - \gamma_m \right\} \\
\sum_{r} x_{ijmr} = y_{ijm} \\
v_{am} = \sum_{ijr} \delta_{amr} x_{ijmr} \\
x_{ijmr} \geq 0
\end{align*}
\]

Subject to:
\[
\sum_{m} y_{ijm} = d_{ij}
\]

Solution:
\[
y_{ijm} = d_{ij} \frac{\exp \left( \gamma_m - \theta \min_{r} c_{ijmr} \right)}{\sum_{n} \exp \left( \gamma_n - \theta \min_{r} c_{ijnr} \right)}
\]
Actual Implementation

4-step demand model

Trip tables

Static assignment

LOS skims for all possible trips
Conclusions on Integration of 4-Step and UE

- What do modelers want?
  - Large regional networks w/high level of spatial resolution (4,000-5,000 zones and even more)
  - Numerous travel and population segments for better representation of behavior (purpose, income, gender, etc)
- Dead-end technology:
  - Both 4-step and UE are inherently limited
  - Integration is hampered by incompatible segmentation
4-STEP INTEGRATED WITH DTA
Incompatible Temporal Resolution

- 4-step operates with broad time-of-day periods and fractional trips
- DTA requires finer demand slices (15 min) and discrete trips
- Split factors are applied (developed from household survey or traffic counts) with subsequent rounding up the number of trips
Slicing & Integerizing Trip Tables

6:00am – 9:00am

6:00am – 6:15am

0.5  1.6
0.1  2.8

6:15am – 6:30am

1.5  1.6
0.1  3.2

8:45am – 9:00am

0.5  1.6
0.1  2.4

PB, New York, NY, May 22, 2014
“Massaging” Trip Tables

- Trip tables from 4-step model after slicing and integerizing do not replicate traffic counts with fine temporal resolution.
- Matrix adjustment is common practice to match link & turn counts.
- Static & dynamic matrix adjustment algorithms are improving.
Matrix Adjustment Methods

- Start with seed matrix (daily, period-specific, hour-specific)
- Define targets to match and closeness function:
  - Link & turn counts (total or by vehicle class; daily, period-specific, hourly)
- Define structural preservation criteria:
  - Preserve trip distribution (daily, period, hour)
    - TAZ-to-TAZ
    - District-to-district
  - Preserve marginals (daily, period, hour)
  - Preserve TLD (daily, period, hour)
- Form optimization program and find a solution (or step towards optimum)
- Equilibrate optimization with assignment
Limited Value of Trip Table Adjustment

- This is a short term solution for certain projects (highway operations) when demand can be considered fixed
- Problematic for long-term planning studies:
  - How adjustments could be carried over into future?
  - Replace demand model with simple trip table factoring?
  - Feedback?

4-step → Sliced trip tables → Adjusted trip tables → DTA
Equilibration is Essential for Long-Term Studies

- Future demand growth can exceed highway capacity:
  - UE allows for V/C > 1
  - DTA with unrealistic demand would not work
- Equilibration can solve this problem:
  - Only if elastic trip generation and time-of-day choice models are applied (problematic with 4-step)
  - Trip distribution and mode choice may not be enough
Conclusions on Integration of 4-Step and DTA

- DTA is used as complementary tool for certain studies most frequently short-term
- 4-step is equilibrated with UE and then trip tables are additionally adjusted for DTA
- No promising avenue for 4-step & DTA integration and equilibration:
  - Inherent limitations of 4-step w.r.t. temporal resolution and time-of-day choice
  - Feedback from DTA to 4-step is not clear
ACTIVITY-BASED MODELS OF TRAVEL DEMAND
## Standard Features of ABMs in Practice in US, 2001-2014

<table>
<thead>
<tr>
<th>Feature</th>
<th>ABM</th>
<th>4-Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main unit of travel</td>
<td>Tour (closed chain of trips)</td>
<td>Trip</td>
</tr>
<tr>
<td>Structural objects for modeling</td>
<td>Individual microsimulation of persons and households</td>
<td>Aggregate zone-to-zone flows (trip tables)</td>
</tr>
<tr>
<td>Travel generation mechanism</td>
<td>Derived from participation in activities</td>
<td>Attributed to population <em>a priori</em></td>
</tr>
</tbody>
</table>
Daily activity patterns have related travel patterns, which are expressed as tours (account for entire daily activity chain).
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>
Tour Mode Consistency

Work Tour

Zone 1

Zone 2

Zone 3

Work-Based Tour

Zone 4

Bus to Work = Drive alone not available for lunch
ABM Basics: Microsimulation

- Synthetic population is created that represents the actual population
- Travel is explicitly modeled for each person/household
- Monte Carlo simulation is used instead of fractional probability aggregation: discrete choices made for each traveler
- Model outcome looks like a large HH survey
- Results are aggregated and:
  - Assigned to transport networks
  - Compiled into reports
Fractional Probability

Tour

- Destination 1 (0.15)
  - Mode 1 (0.05)
  - Mode 2 (0.03)
  - Mode 3 (0.07)

- Destination 2 (0.75)
  - Mode 1 (0.15)
  - Mode 2 (0.25)
  - Mode 3 (0.35)

- Destination 3 (0.10)
  - Mode 1 (0.05)
  - Mode 2 (0.02)
  - Mode 3 (0.03)
Microsimulation

Tour

- Destination 1 (0.15)
  - Mode 1 (0.15)
  - Mode 2 (0.25)
  - Mode 3

- Destination 2

- Destination 3 (0.10)
Individual Parameter Variation

- IPV technique was successfully used for probabilistic VOT (SFCTA, CMAP), propensity to walk (CMAP), license plate rationing (NY).
- IPV can be used in a similar way for all types of payment media and individual discounts.
- IPV requires a microsimulation framework; it should also be applied for network simulations.
VOT Distribution (SFCTA ABM)

- Income $0-30k (Mean: $6.01)
- Income $30-60k (Mean: $8.81)
- Income $60-100k (Mean: $10.44)
- Income $100k+ (Mean: $12.86)
Temporal resolution and time-use constitute clear advantages of ABM:
- Activity participation requires time
- Every person has 24 hours a day

Temporal resolution is essential for:
- Addressing policies like congestion pricing
- Integration with advanced network simulation models

Examples of ABM time-use follow:
Tour TOD choice

Work tour to schedule
Tour TOD choice

Work tour to schedule

Considerations for departure time:
• Office hours (7-10)
• Avoid congestion (10+)
• Give ride to child (7)
Tour TOD choice

Work tour
Tour TOD choice

Considerations for arrival time:
- Office hours ($\leq 20$)
- Avoid congestion ($< 16$)
- Tennis before dark ($< 17$)
Tour TOD choice

Considerations for duration:
- 8 work hours
- Finish presentation for workshop

Work tour

5 10 15 23
Time-Use Concept: Sequential Processing of Tours

1-Work
2-Discretionary joint
3-Shopping individual
Time-Use Concept: Sequential Processing of Tours

1-Work
7-17

2-Discretionary joint

3-Shopping individual
Time-Use Concept: Sequential Processing of Tours

1-Work
7-17

2-Discret
20-23

3-Shopping individual
Time-Use Concept: Sequential Processing of Tours

- 1-Work: 7-17
- 3-Sh: 18-19
- 2-Discret: 20-23
Persons By TAZ and Hour (Daytime Population, Atlanta, ARC ABM)
Completed ABMs in the United States in Practice

- Seattle
- San Francisco
- Sacramento
- Lake Tahoe
- San Diego
- Bay Area
- Portland
- Oregon
- Chicago
- Miami
- Atlanta
- Columbus
- Denver
- Atlanta

Legend:
- Developed by PB
- Developed by others
- CT-RAMP Family
NY Model Area: 28 Counties

- 20,000,000 population
- 100 population segments
- 4,000 TAZs
- 4 time-of-day periods
- 6 travel purposes
- 10 motorized modes
- 4 macro / 11 area types
Chicago (CMAP) Region

- Population: 10.5 million

- Modeling Region
  - 21 counties in 3 states
    - Neighboring MPOs
      - SE Wisconsin
      - NW Indiana
  - 1,944 TAZs

- Road Network
  - 15.0K nodes
  - 44.3K links

- Rail Network
  - 6.6K nodes
  - 19.5K links
Income distribution of users of ML and GPL

Income of express lane vs. general purpose lane users, annual household income, in thousands of dollars

**Legend**

<table>
<thead>
<tr>
<th>25TH PERCENTILE</th>
<th>MEDIAN</th>
<th>75TH PERCENTILE</th>
<th>95TH PERCENTILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>5TH PERCENTILE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- I-290 EXPRESS
- I-290 GENERAL PURPOSE
- I-55 EXPRESS
- I-55 GENERAL PURPOSE
- I-90 EXPRESS
- I-90 GENERAL PURPOSE

Source: CMAP analysis.
CT-RAMP Family of ABMs Developed by PB SAG

- Coordinated Travel Regional Activity-based Modeling Platform

Main features:
- Explicit intra-household interactions and Coordinated DAP (CDAP)
- Continuous temporal dimension
- Integration of activity generation, location, and TOD sub-models
- Sensitive to a wide range of socio-economic variables, transportation costs/accessibilities, and land-use changes
- JAVA-based package for ABM construction
Members of CT-RAMP Family

- **1\textsuperscript{st} generation:**
  - Columbus, OH (MORPC) – in practice since 2004
  - Lake Tahoe, NV (TMPO) – in practice since 2006
  - Atlanta, GA (ARC) – in practice since 2009
  - San-Francisco Bay Area, CA (MTC) – in practice since 2010

- **2\textsuperscript{nd} generation:**
  - Chicago, IL (CMAP) – in practice since 2011
  - San-Diego, CA (SANDAG) – in practice since 2012
  - Miami, Fl (SERPM) – in practice since 2012

- **3\textsuperscript{rd} generation:**
  - Phoenix/Tucson, AZ (MAG) – started in 2010
  - Jerusalem, Israel (JTMT) – started in 2011
  - Ohio 3C Project – started in 2013:
    - Columbus (MORPC)
    - Cleveland (NOACA)
    - Cincinnati (OKI)
  - LA, CA (SCAG) – started in 2013 (Hybrid of CT-RAMP and MDCEV)
  - Nashville, TN (NMPO) – started in 2013 (PopSyn)
ADVANCED ABM
INTEGRATED WITH UE
What is Different with ABM?

- Complicated chains of choices with structural changes in the list of agents instead of predetermined matrix of choices pertinent to 4-step
- Entropy-maximizing formulation for demand terms is theoretically possible but impractical because of dimensionality
- Microsimulation of crisp choices instead of fractional probabilities
Practical Methods: Enforcement & Averaging

- Simple feeding back LOS variables does not ensure convergence
- 2 ways to ensure convergence by iterating:
  - Enforcement to ensure replication of “crisp” individual choices:
    - Theoretical foundation
    - Empirical strategies
  - Averaging:
    - Continuous LOS variables (skims)
    - Link volumes (before skimming)
    - Trip tables
Enforcement Methods

- Re-using same random numbers / seeds:
  - Each household / person has a fixed seed
  - Structural stability of decision chains by reserving choice placeholders

- Gradual freezing of travel choices:
  - Subsets of households
  - Travel dimensions

- Analytical discretizing of probability matrices:
  - Avoiding Monte-Carlo (no random numbers!)
Averaging Methods (NY BPM)

- Microsimulation model
- Mode & TOD trip tables
- Conventional static assignment
- Link volumes
- Link times
- OD skims

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New Challenge – Continuously Distributed VOT: Chicago Pricing

ABM

- Basic VOT estimated for each travel purpose and person type
- Situational variation of VOT applied for each person based on lognormal distribution – essential for pricing studies
- Car occupancy accounted by cost sharing:
  - VOT for HOV2 is 1.6 of highest participant VOT
  - VOT for HOV3+ is 2.3 of highest participant VOT
- For static assignments VOT has to be aggregated across individuals into discrete vehicle classes
## Resulted Classes for Assignment

<table>
<thead>
<tr>
<th>Vehicle type &amp; VOT</th>
<th>Non-toll SOV</th>
<th>Non-toll HOV2</th>
<th>Non-toll HOV3+</th>
<th>Toll SOV</th>
<th>Toll HOV2</th>
<th>Toll HOV3+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto low</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Auto high</td>
<td>7</td>
<td>9</td>
<td>11</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Commercial</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>Light truck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
</tr>
<tr>
<td>Medium truck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18</td>
</tr>
<tr>
<td>Heavy truck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>External low</td>
<td>21</td>
<td>23</td>
<td>25</td>
<td>22</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>External high</td>
<td>27</td>
<td>29</td>
<td>31</td>
<td>28</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>Airport low</td>
<td>33</td>
<td>35</td>
<td>37</td>
<td>34</td>
<td>36</td>
<td>38</td>
</tr>
<tr>
<td>Airport high</td>
<td>39</td>
<td>41</td>
<td>43</td>
<td>40</td>
<td>42</td>
<td>44</td>
</tr>
</tbody>
</table>
Conclusions on Integration of ABM and UE

- Effective & efficient practical strategy:
  - MSA of link volumes and
  - MSA on trip tables
- Enforcement can be applied effectively
- Segmentation incompatibility is exacerbated due to continuous VOT and other individual variables of ABM:
  - Better network model is needed
ABM INTEGRATED WITH DTA
Integration Issue DTA-to-ABM

Microsimulation ABM

List of individual trips

Individual trajectories for the current list of trips

LOS for the other potential trips?

Microsimulation DTA
Possible Surrogate (SHRP 2 C10)

- Microsimulation ABM
- List of individual trips
- Microsimulation DTA
- Aggregate LOS skims for all possible trips

?
What’s wrong with feeding back aggregate LOS OD skims?

- Aggregate OD LOS skims is only a surrogate for consistent individual path LOS:
  - Back to 4-step resolution and aggregation biases
- Infeasible to support individual level of segmentation pertinent to ABM (“curse of dimensionality”):
  - VOT categories (7-8 at least)
  - Occupancy categories (3 at least)
  - Departure time bins (15 min at least)
- Behaviorally non-appealing:
  - No relation to actual individual experience, learning, or adaptation
2-Level Equilibration Schema
Developed by PB SAG

Temporal equilibrium to achieve individual schedule consistency

- Microsimulation ABM
- Sample of alternative origins, destinations, and departure times
- Individual trajectories for potential trips
- List of individual trips
- Consolidation of individual schedules (inner loop for departure / arrival time corrections)
- Individual trajectories for the current list of trips
- Microsimulation DTA
Schedule Consistency

<table>
<thead>
<tr>
<th>Activity $i=0$</th>
<th>Activity $i=1$</th>
<th>Activity $i=2$</th>
<th>Activity $i=3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trip $i=1$</td>
<td>Trip $i=2$</td>
<td>Trip $i=3$</td>
<td></td>
</tr>
</tbody>
</table>

Travel $T_i$
Duration $d_i$
Arrival $\tau_i$
Departure $\pi_i$

Schedule $\theta = \{\pi_i\}$
Schedule Adjustment

Find new schedule close to previous durations and departures

\[
\min \left\{ \sum_i \left( x_i \ln \frac{x_i}{d_i} + y_i \ln \frac{y_i}{\pi_i} \right) \right\}
\]

Daily consistency

\[
\sum_i (x_i + t_i) = 24
\]

Departure time

\[
y_i = \sum_{j \leq i} (x_j + t_j)
\]

Solution

\[
x_i = k \times d_i \times \prod_{j \geq 1} \frac{\pi_j}{y_j}
\]

Changed travel times
Agent vs. Simulated Individual

- **Intelligence:**
  - Active autonomous behavior and control
  - Knowledge-level interaction and behavior activation instead of method invocation
  - **Can change parameters and decision rules to achieve goals**

- **Constrained & dynamically updated information:**
  - Learn about environment and each other, form choice sets
  - Contagion, stigmergy, referencing, modality

- **Interact with each other and not with environment only:**
  - Emergent collective behavior (complex, non-linear, discontinuous)
  - Competition, bids, offers, negotiations instead of densities/logsums
  - **Cooperation, group decision-making, explicit intra-household and inter-household interactions**
Dynamic Choice Set

- In the focus of research on choices with large number of alternatives:
  - Location choices
  - Network route choice
- “Mental Maps” and gradual learning [Arentze & Timmermans, 2000-2013]:
  1. Start with limited choice set (can be a single alternative)
  2. Choose the best alternative
  3. Evaluate satisfaction level (not a standard RUM!)
  4. If not, add one more “probe” alternative to choice set, go to 2
Learning about Space from Individual Trajectories (Dynamic Choice Set)

- One implemented trip provides individual learning experience w.r.t. multiple destinations [Tian & Chiu, 2014]

Intermediate nodes visited on the way:
- Travel time and cost experienced
- Parking conditions may not
Sampling of Trip Destinations to Avoid Full Skim Proliferation

- (Standard) destinations are sampled in ABM for efficiency:
  - 30 out of 20,000 MAZ for each modeled tour & trip
  - Sampled randomly with importance (size variable and distance)
  - No memory, experience, or learning

- (Suggested) Intelligent dynamically updated choice set for each individual and activity:
  - Efficient accumulation of individual trajectories in microsimulation process
  - Behaviorally appealing
Dynamic Destination Choice Set

10 randomly sampled destinations for individual for activity

Add visited locations for individual with positive size variable for activity

Add 5 randomly sampled destinations

Drop locations from individual set for activity if exceeds 30

Crude skims

Actual choice

Simulated trajectory

Visited locations
## LOS for Dynamically Updated Dest. Choice Set for Each Person & Activity

<table>
<thead>
<tr>
<th>Orig</th>
<th>Dest</th>
<th>Departure time 6:00-6:15</th>
<th>Departure time 6:15-6:30</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Experienced trajectory time</td>
<td>Experienced trajectory cost</td>
</tr>
<tr>
<td>Home</td>
<td>1001</td>
<td>10 min</td>
<td>0 cents</td>
</tr>
<tr>
<td>Home</td>
<td>2050</td>
<td>15 min</td>
<td>0 cents</td>
</tr>
<tr>
<td>Home</td>
<td>0005</td>
<td>20 min</td>
<td>0 cents</td>
</tr>
<tr>
<td>Home</td>
<td>8900</td>
<td>22 min</td>
<td>50 cents</td>
</tr>
<tr>
<td>Home</td>
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<td>30 min</td>
<td>120 cents</td>
</tr>
<tr>
<td>Home</td>
<td>3344</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PB, New York, NY, May 22, 2014
LOS Variables for Outer Loop

- (I) Individual trajectories by departure time period for the same driver (personal learning experience), if not:
  - (II) Individual trajectories for the same OD pair by departure time period across similar individuals (what driver can hear from other people through social networks), if not:
    - (III) Aggregate OD skims by departure time period (advice from navigation device)
Conclusions on Integration of ABM and DTA

- ABM-DTA integration is the most promising avenue:

- First ABM-DTA integration projects:
  - SHRP 2 C10:
    - Sacramento, Jacksonville, Tampa
  - MPO-sponsored (all PB):
    - CMAP, SANDAG, JTMT

- For small metropolitan areas under 1 million ABM-DTA integration is already realistic with many DTA platforms

- For large metropolitan areas DTA is still a challenge:
  - MatSim offers one of the first solutions
NY BPM – MatSim Integration Demonstration

- Promising real-size exercise for the mega-region of NY:
  - 20 million people handled by NY BPM to generate demand patterns
  - Full-size regional highway and transit networks handled by MatSim for entire-day simulation (24 hours)

- Next step:
  - Full integration of the NY ABM with MatSim utilizing innovative integration paradigm