Integrated ABM-DTA Approach:
SHRP2 C04 Research Status

Peter Vovsha, Principal Investigator
Rosella Picado, Project Manager
Parsons Brinckerhoff
1. ABM-DTA INTEGRATION STATE OF THE ART & PRACTICE
## Intensive Research and First Practical Applications

<table>
<thead>
<tr>
<th>Project</th>
<th>Region</th>
<th>ABM</th>
<th>DTA</th>
<th>Status</th>
<th>Integration</th>
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<tbody>
<tr>
<td>SHRP C10A</td>
<td>Jacksonville, FL</td>
<td>DaySim</td>
<td>Transims</td>
<td>Completed</td>
<td>LOS skims</td>
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<tr>
<td>SHRP C10B</td>
<td>Sacramento, CA</td>
<td>DaySim</td>
<td>DynusT</td>
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<td>LOS skims</td>
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<tr>
<td>CMAP</td>
<td>Chicago, IL</td>
<td>CT-RAMP1</td>
<td>DynaSmart</td>
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<tr>
<td>SANDAG</td>
<td>San Diego, CA</td>
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<td>AimSun</td>
<td>DTA setting</td>
<td>Individual</td>
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<td>JTMT</td>
<td>Jerusalem, Israel</td>
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<td>Dynameq</td>
<td>DTA setting</td>
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<tr>
<td>C10/ARC</td>
<td>Atlanta, GA</td>
<td>CT-RAMP1</td>
<td>DynusT</td>
<td>On-going</td>
<td>Individual</td>
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<tr>
<td>C10/ODOT</td>
<td>Columbus, OH</td>
<td>CT-RAMP2</td>
<td>DynusT</td>
<td>On-going</td>
<td>Individual</td>
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<tr>
<td>C10/SFCTA</td>
<td>San-Francisco, CA</td>
<td>CHAMP</td>
<td>FastTrips</td>
<td>On-going</td>
<td>TBD</td>
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<tr>
<td>C10/BMC</td>
<td>Baltimore, MD</td>
<td>TourCast</td>
<td>DTALite</td>
<td>On-going</td>
<td>Individual</td>
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# Project Ingredients

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<th>ABM</th>
<th>DTA</th>
<th>Integration</th>
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</table>
| • Improvements to match DTA needs:  
  • Enhanced temporal resolution  
  • Individual schedule consistency  
  • Dynamic destination choice sets  
  • Explicit driver and passenger roles in carpools | • Improvements to match ABM needs:  
  • Individual route choice (VOT, walk propensity)  
  • Database of individual trajectories  
  • Selective time-dependent shortest paths (TDSP) | • 3 levels (loops):  
  • Level 1 (global demand response)  
  • Level 2 (temporal equilibrium, individual schedule consistency)  
  • Level 3 (within-day adjustments; trip chain loading)  
  • New “Gap” measures for convergence |
New CT-RAMP “Integrable” w/DTA

• Enhanced temporal resolution:
  – Continuous trip departure time choice

• Individual schedule consistency:
  – Trip departure time and activity duration generated by ABM consistent with travel time generated by DTA
  – Additional important constraint on the state of the system

• Dynamically updated destination choice sets:
  – Individual learning and adaptation instead of random sampling
  – Moving towards AgBM

• Explicit driver and passenger roles in carpools:
  – Translation of person trips and tours into vehicle trip and tours
New DTA “Integrable” w/ABM

• Meso-level DTA for regional planning models:
  – More detail for route choice (occupancy, VOT)
  – Less detail for vehicle simulation

• Individual route choice (VOT):
  – VOT distribution essential for pricing studies
  – Consistency between mode choice in ABM and route choice in DTA

• Database of individual trajectories:
  – Mining individual trajectories and sub-trajectories (experienced individual LOS)

• Selective TDSP:
  – API for selective TDSP call (expected individual LOS)
Probabilistic VOT

![Graph showing the value of time for different income brackets: $0-30k (Mean: $6.01), $30-60k (Mean: $8.81), $60-100k (Mean: $10.44), $100k+ (Mean: $12.86).]
2. ABM-DTA INTEGRATION PRINCIPLES
Conventional integration

- List of individual trips
- Microsimulation ABM
- Microsimulation DTA
- Aggregate LOS skims for all possible trips
Limitations of feeding back aggregate LOS OD skims

• Skims is only a surrogate for consistent individual path LOS:
  – Back to 4-step resolution and aggregation biases
• Infeasible to support 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)
  – All this for (#TAZs)$^2$
• Behaviorally non-appealing:
  – No relation to individual experience, learning, or adaptation
Proposed Approach for Day-Level Integration

- Microsimulation ABM
  - Dynamically updated sample of origins, destinations, and departure times
  - Individual trajectories & TDSP for potential trips

- List of individual trips
  - Consolidation of individual schedules (inner loop for departure time adjustment)
  - Individual trajectories for the current list of trips

- Microsimulation DTA

Temporal equilibrium to achieve individual schedule consistency
3. INTERNAL LOOP OF INDIVIDUAL SCHEDULE ADJUSTMENTS

Taking advantage of individual trajectories
Essence of Internal Loop (Level 2)

• Sequence of trips, destinations, and modes is fixed for each individual
• Joint equilibration of trip departure time and route choices ("extended DTA")
• Take full advantage of individual trajectories generated by DTA as the best measure of LOS
• Ensure individual schedule consistency and evaluate schedule feasibility/desirability
Individual Schedule Consistency

\[
\begin{align*}
\text{Travel} & \quad T_i \\
\text{Duration} & \quad d_i \\
\text{Arrival} & \quad \tau_i \\
\text{Departure} & \quad \pi_i \\
\end{align*}
\]

\[
\text{Schedule} \quad \theta = \{\pi_i\}
\]
Schedule Delay Cost

- \( U = \alpha \times T + \beta \times SDE + \gamma \times SDL + \delta \times L \)

- In presence of random travel times:
  - \( f(T) \) – travel time distribution
  - \( E(U) \) – expected utility dependent on \( f(T) \) and departure time/PAT
  - Improvement of reliability in terms of \( f(T) \) can be evaluated in terms of \( E(U) \)

- Considerable body of literature:
  - SP estimates: \( \gamma \geq \alpha \)
Individual Schedule Adjustment

• Schedule deviation minimization approach:
  – Generalization of schedule delay approach developed by K. Small for a single trip
  – Objective function terms with importance weights summed over all trips/activities:
    • \( \alpha \times \max(\text{PlanActDur} - \text{AdjActDur}, 0) \) // shorter
    • \( \beta \times \max(\text{AdjActDur} - \text{PlanActDur}, 0) \) // longer
    • \( \lambda \times \max(\text{PlanTripDep} - \text{AdjTripDep}, 0) \) // depart earlier
    • \( \gamma \times \max(\text{PlanTripDep} - \text{AdjTripDep}, 0) \) // depart later
    • \( \mu \times \max(\text{PlanTripArr} - \text{AdjTripArr}, 0) \) // arrive earlier
    • \( \nu \times \max(\text{PlanTripArr} - \text{AdjTripArr}, 0) \) // arrive later
Individual Schedule Adjustment

• Results in LP problem with entire-day schedule consistency constraints
• Fully consistent with schedule delay models and TOD choice
• Applied for entire HH and accounts for joint trips
• Works as a natural “randomizer” for trip departure time
Taking advantage of simulated individual trajectories as the best measure of actual LOS

4. MINING AND DISSECTING INDIVIDUAL TRAJECTORIES
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
Direct Full Indexing of Trajectories and Sub-Trajectories with LOS Accumulation (Long Format)

• Each trajectory is dissected into $N \times (N-1)/2$ sub-trajectories and each of them is added to the bank:
  – Car occupancy
  – VOT
  – OTAZ
  – DTAZ
  – Departure time
  – Travel time
  – Travel distance
  – Toll
  – Toll equivalent in min
Bank of Trajectories and Mining

Quick mining:

Filter user(s):

- Filter trajectories that span departure time bin (TOD)
- Filter sub-trajectories that start from OTAZ and TOD
- Filter sub-trajectories that include DTAZ

Aggregation if more than one found:

- Give precedence to the modeled individual
- Give precedence to later iterations
- Averaging rules (max, min, mean, STD)
5. EQUILIBRATION

How the external and internal loops can be combined
Travel “Stress”

• Behavioral meaning:
  – Experienced travel times unreasonable and/or very different from the expected travel times
  – Individual will seek other travel choices

• Formal meaning for ABM-DTA equilibration:
  – Empirical “gap” measure
  – Generated individual activity-travel pattern does not belong to stationary solution
  – Entire daily pattern has to be re-generated

• Practical daily measures of travel “stress“:
  – Total daily travel time
  – Travel overhead (travel time / out-of-home activity time)
  – More elaborate measures explored
## Travel “Stress” Thresholds

<table>
<thead>
<tr>
<th>Person type</th>
<th>Max total travel time, min</th>
<th>Travel time overhead</th>
<th>Min total activity time for overhead, min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1=Full-time worker</td>
<td>240</td>
<td>0.5</td>
<td>180</td>
</tr>
<tr>
<td>2=Part-time worker</td>
<td>180</td>
<td>0.8</td>
<td>120</td>
</tr>
<tr>
<td>3=University student</td>
<td>240</td>
<td>0.8</td>
<td>120</td>
</tr>
<tr>
<td>4=Non worker U65</td>
<td>180</td>
<td>1.5</td>
<td>60</td>
</tr>
<tr>
<td>5=Retiree</td>
<td>150</td>
<td>1.5</td>
<td>60</td>
</tr>
<tr>
<td>6=Driving-age school child</td>
<td>150</td>
<td>0.4</td>
<td>120</td>
</tr>
<tr>
<td>7=Pre-driving-age school child</td>
<td>120</td>
<td>0.4</td>
<td>120</td>
</tr>
<tr>
<td>8=Preschool child</td>
<td>120</td>
<td>0.8</td>
<td>120</td>
</tr>
</tbody>
</table>

- Person is “stressed” if either the max time is reached or max overhead is reached in combination with min activity time
- HH is “stressed” if at least one person is “stressed”
“Stressed” and “Un-stressed” HHs

Microsimulation ABM

List of individual trips

Dynamically updated sample of origins, destinations, and departure times

Individual trajectories & TDSP for potential trips

Consolidation of individual schedules (inner loop for departure time adjustment)

Individual trajectories for the current list of trips

Microsimulation DTA

Stressed HHs

All HHs