Progress in the Development of the Agent-based Dynamic Activity Planning and Travel Scheduling (ADAPTS) Microsimulation Model

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Overview

- Introduction and Motivations
- ADAPTS Framework
- Current work on the ADAPTS model
  - Activity generation
  - Activity planning strategies
  - Attribute planning (destination choice)
  - Activity scheduling
  - Integration with Traffic Assignment
- Pricing Simulation Results
- Discussion / Conclusions
Overall Integrated Land-Use Transportation Model Framework

- Transportation System
- Population Synthesis
- Regional Economy Land/Job Markets

- Vehicle Ownership
- Household Composition
- Home/Work Location choice

- Vehicle Transaction
- Household Long-Term Context
- Work/Home Change and Choice

- Long-term Decision Making
  - Activity/Travel Model
  - Freight Model

- Short-term Simulation
- Traffic Simulation

ADAPTS Model
Introduction and Motivation
Activity based modeling

- Activity-based modeling
  - Microsimulation models which develop individual activity schedules
  - Usually at the household or individual level
  - Pattern of activities and travel explicitly developed for entire population

- Advantages (from having more of a behavioral basis):
  - Can represent time very accurately
  - Represent response to policy changes very well
  - Explicitly captures trip chaining response

- Two dominant paradigms:
  - Econometric
  - Computational Process Model

- Currently lacking:
  - Representation of planning dynamics
  - Realistic activity planning
  - Integration with traffic simulation – usually done through feedback
Issues in Activity-Based Modeling

- Preset activity priority order:
  - Activities added to schedule and attributes picked in fixed order
  - In other models: activities added in order of assumed priority
  - Does not match observations from data (Roorda et al. 2005)

- Fixed order of attribute scheduling:
  - Ex: Party > Duration > Location > Mode > Time
  - Gives fixed dependencies in the decisions
  - Again, does not match actual scheduling process
    - seen in CHASE, OPFAST, UTRACS (our GPS survey), etc.

- Scheduling planning dynamics
  - Order of decisions can impact subsequent decisions
  - Impulsive/unexpected events in simulation or scenarios
  - Many have entire schedule generated then executed

- May lead to errors modeling behavioral-based policies
Scheduling Order Example

A) Impulsive Shop - Preplan Eat Out

Before Change

After Change

B) Preplan Shop - Impulsive Eat out

Before Change

After Change
Motivation for ADAPTS

- When and how activity planning decisions are made can impact final daily activity pattern
  - In example, both situations start with same pattern
  - Small policy change creates large differences in pattern, depending only on activity planning

- ADAPTS: adds element of activity planning, to activity generation and activity scheduling
  - Simulation of planning steps

- Account for planning dynamics
  - when is each decision made in relation to other decisions, activities, schedule, etc.

- Represent macro-level changes from impacts of policies on planning dynamics at individual level
ADAPTS Model Framework
Framework - Introduction

- ADAPTS scheduling process model:
  - Simulation of how activities are planned and scheduled
  - Extends concept of “planning horizon” to activity attributes
  - Time-of-day, location, mode, party composition

- Fits within overall framework of activity-based microsimulation model
  - Constraints from long-term simulation (land-use model)
  - Combined with route choice and traffic simulation

- Models being generated for Chicago region
  - Datasources: UTRACS (GPS) Survey, CMAP household travel survey, CMAP land-use database, Census 2000, CHASE, etc.
ADAPTS Simulation Framework

Initialize Simulation
- Initialize World
- Synthesize Population
- Generate routines

For each timestep

Household Planning

Household Schedule
Household Memory
Individual Schedules
Individual Memory
Social Network

Information Flow
Simulation Flow

Write Trip Vector
Traffic Assignment

Land Use
Institutional Constraints
Network LOS
- ADAPTS planning and scheduling framework

- Handles at each timestep:
  - Generation
  - Planning
  - Scheduling

- Generation, planning and scheduling can occur at different times for same activity

- Core of the framework is the Attribute Plan Order Model

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**ADAPTS Planner/Scheduler**

1. **At timestep** $t$
   - **Generate new activity**
   - **Attribute Planning Order Model**
     - Yes
     - **Update existing activity(s)**
     - No
   - **Set Plan Flags:** ($T_{time}, T_{loc}$, etc.)
   - **Execute activity**

**Activity Generation**

- **Time-of-Day** $t = T_{time}$
- **Party** $t = T_{with}$
- **Destination choice** $t = T_{loc}$
- **Mode Choice** $t = T_{mod}$

**Activity Planning**

**Activity Scheduling**

**Resolve Conflicts**

- **Conflict Resolution Model**
  - Yes
  - **Executed Schedule**
  - No
Completed Components of ADAPTS

- Rest of discussion will focus on core components of ADAPTS which have been completed
  - Activity Generation (1st Stage)
  - Activity Planning Strategies
  - Attribute Planning (Destination Choice)
  - Activity Scheduling

- Demonstration of current system
Activity Generation
Activity Generation

- Activity generation through set of decision trees
  - Classify HH/Person by socio-demographics

- Generation rates drawn from probability distribution fit at each node
  - Distributions estimated from 7-day CHASE data
  - Fit to Chicago 1-day survey through updating

Node 1
N = 367
Social Avg. = 0.3244
Social Std. dev. = 0.3505

Node 2
N = 125
Social Avg. = 0.4388
Social Std. dev. = 0.4341

Node 3
N = 242
Social Avg. = 0.2652
Social Std. dev. = 0.2806

Node 4
N = 25
Social Avg. = 0.6836
Social Std. dev. = 0.3767

Node 5
N = 100
Social Avg. = 0.3776
Social Std. dev. = 0.4258
Activity Generation: Correction Factors

- Using observed generation rates gives incorrect results
  - Due to collisions (i.e. activity conflicts)
  - Activities split, postponed, deleted, etc.
- Unobserved planned activity generation
- Try to correct generation distributions through simulation:
  - $f_i^* = S(\lambda_i f_i)$, minimize $(f_i^* - f_i) \forall i \in \text{activity types}$
  - $\lambda_i f_i$ approximates unobserved planned activity generation
  - Must be solved simultaneously

\begin{align*}
\lambda_1 &= 1.0 \\
\lambda_2 &= 1.26 \\
\lambda_3 &= 1.53 \\
\lambda_4 &= 1.45
\end{align*}
Activity Generation: Validation

- Application to Chicago-region
  - Calibrated to 2007 data
  - Backcast validation to 1990 HHTS
  - Validated by activity-type, HH Type, etc.

- Currently updating to include generation dynamics
  - System of simultaneous hazard equations for generation
Activity Planning Strategies
Activity Planning in ADAPTS

- Activities generated and planned dynamically
- Conditional decision making, dependent on
  - Past history
  - Current plans
  - Situation/resource/capacity/household constraints
- Need to know when activities/attributes are planned

- Activity planning order model
  - General categories of when activity generation and attribute planning occur in the schedule
Activity Planning Order Framework

- Assign plan horizon to each attribute
  - After activity generated

- Plan order model process
  - Assigns attribute flexibility
  - Get activity plan horizon
  - Attribute plan horizons

- Plan horizons for each attribute based on:
  - Attribute flexibilities
  - Activity plan horizon
  - General activity attributes
  - Socio-demographics, etc.

- Defines the *meta-attributes* of the activity attributes
Planning Models Discussion

- Estimated set of ordinal/multivariate probit models
  - All models have acceptable goodness of fit
  - Significant improvement over null models
  - Generally have parameters significant at 0.05 level

- Determines how activity flexibility/plan horizon impact attribute planning
  - More expected planning/scheduling effort => more preplanning

- Includes policy sensitive variables relating to:
  - Telework and flex scheduling
  - ICT usage rates
  - Generalized travel costs
  - Endogenous scheduling variables (average frequency, duration)
Destination Choice Modeling
Destination Choice

- Need conditional model of destination choice
  - Represent impact of planning dynamics
  - Core focus of ADAPTS development

- Planning influences indirectly through choice set
  - No need for a full set of conditional models

- Planning constrained destination choice
  - Observe what has already been planned before choice
  - Space-time constrains based on previous plan
  - In addition to constraints from fixed activities
Planning Constrained Destination Choice

(a) *Shop* planned first

(b) *Shop* planned after *Social*

- **Fixed activity**
- **Planned activity**
- **Constraint from Fixed Activity**
- **Constraint from Modifiable Activity**
Planning constraints determine the available time
- Assuming known values for LOS between zones
- Conditional choice set formation using available travel time
- Depends on plan time of each individual attribute

Planning constraints on Shop Activity:
- If Social timing and location known
  - Travel time available = end of Social to start of Work, calculated starting from Social location
- If Social location known
  - Travel time available = end of Home to start of Work, calculated starting from Social location less travel time from Home to Social
- If Social timing known
  - Travel time available = end of Social to start of Work, calculated ending at the work location (no inbound trip to Shop used)
  - Shop location choice then constrains Social location choice
Choice set formed using plan-constrained prism
- Importance sampling (on travel time, employment totals) of zones
- Clearly requires planning data to determine choice set

Use variety of Competing-Destinations model:

\[ V_{in} = \beta_T T_{in} + \beta_I \ln(I_{in}) + \beta_R R_{in} + \sum_{j} \beta_j \ln(A_{ij}) + \sum_{k} \beta_k \ln(E_{ik}) + \sum_{k} \theta_k C_k + \ln\left(\frac{1}{p(i)}\right) \]

Where,
- \( A_{ij} \) = Land use variables
- \( E_{ij} \) = Employment variables
- \( C_k \) = Competition/Agglomeration factor
- \( p(i) \) = Probability of zone being selected into choice set

\[ C_k = \left(\frac{1}{N_{zone} - 1} \sum_{l \neq i}^{N_z} e_{lk} e^{-d_{il}}\right)^{-\frac{d_{il}}{\gamma}} \]
Destination Choice - Validation

- Model estimated for Chicago using 2007 HHTS data
  - Simulated planning data using plan order model
- Compared to same model with no planning constraints on choice set formation
  - Trip time distribution much closer for plan constrained model
  - Higher aggregate $R^2$ (0.602 vs 0.571) over all activities
Activity Scheduling
Scheduling Rules - Overview

- Set of rules for scheduling randomly generated activities
- Attempts to resolve conflicts by modifying each activity
  - series of rules determine how modifications are made
  - System based on the scheduling rules found in TASHA model
- Includes results of conflict resolution model:
  - TASHA – conflict resolution based on heuristic rules
  - New rules – heuristic rules determine how conflict resolution strategy is implemented
  - Possible resolutions for two activities in conflict: delete original activity, modify original, modify conflicting, modify both
- New rules allow for the consideration of more complicated conflict types and deletion operations
- When activities can be truncated, each activity assumed to be truncated proportionally to duration
Scheduling – Overall System

- Based on conflict resolution model
  - Resolution strategy determines rules followed
- For all situations show below:
  - Determines how schedule is modified
  - Based on available time, act. type, resolution type, etc.
  - Insert new activity or drop depending on results

<table>
<thead>
<tr>
<th>Case 1: Inserted Original</th>
<th>Case 2: Overlapped Original</th>
<th>Case 3: Overlap Start</th>
<th>Case 4: Overlap End</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Case 5: Overlap End &amp; Start</th>
<th>Case 6: Insert &amp; Overlap Start</th>
<th>Case 7: Overlap End &amp; Insert</th>
<th>Case 8: Insert/Overlap Start /End</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

Note: New conflict cases exclude all situations with more than 1 activity entirely overlapped.

'Deleted' activity refers to a scheduled activity whose resolution has been set to 'Delete' by the resolution model.
Due to dynamic nature of scheduling, conflicts naturally arise
- Timing, location, resource

Conflict resolution model chooses strategy for resolving conflict
- Currently only for timing
- Uses decision trees
- Strategies based on demographics, constraints, schedule characteristics, etc.
Integration with Traffic Assignment
Integration with Traffic Simulation

- Integration of activity planning/scheduling with traffic assignment
  - As activities are executed generate trip vector
  - Pass to dynamic traffic assignment routine
  - Return locations of each individual at end of timestep
  - Simulates 15 minutes of travel

- Currently testing a number of DTA programs
  - Needs to be able to interact with ADAPTS scheduler
  - Capable of simulating short time periods
  - Many options to test: Dynasmart, Dynamit, Vista, Transims, Aimsun, etc.
Integration with Traffic Simulation

- **Land Use Patterns**
- **Synthetic Population**

**Next Timestep T**

- **Activity Scheduling**
  - Build OD
    - Add trips that start during T
    - Remove trips that ended during T-1

- **Dynamic traffic simulation**

- **Network LOS**
Cordon Pricing Simulation Example
Cordon Pricing Simulation

- Two small-scale ADAPTS simulations have been run for Chicago
  - Baseline scenario: using current LOS
  - Pricing scenario: cordon pricing around downtown in AM and PM peak periods

- Created to demonstrate important features of ADAPTS
  - Determine policy sensitivity
  - Demonstrate dynamic activity planning
Simulation – Cordon Pricing

- AM and PM peak cordon pricing
  - 7-10 AM and 3-6 PM
  - All trips entering downtown (TAZ 54-128)
  - Toll of $10 to enter cordon area
    - No toll within cordon or for outbound trips
Simulation Comparisons

### BEFORE CORDON PRICING

<table>
<thead>
<tr>
<th>Destination</th>
<th>Auto</th>
<th>Walk/Bike</th>
<th>Transit</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOWNTOWN</td>
<td>57%</td>
<td>17%</td>
<td>26%</td>
<td>6.3%</td>
</tr>
<tr>
<td>COOK</td>
<td>82%</td>
<td>11%</td>
<td>7%</td>
<td>48.5%</td>
</tr>
<tr>
<td>DUPAGE</td>
<td>93%</td>
<td>5%</td>
<td>2%</td>
<td>15.1%</td>
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<tr>
<td>KANE</td>
<td>94%</td>
<td>6%</td>
<td>1%</td>
<td>8.3%</td>
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<tr>
<td>LAKE</td>
<td>93%</td>
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<td>2%</td>
<td>9.2%</td>
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<tr>
<td>MCHENRY</td>
<td>94%</td>
<td>6%</td>
<td>0%</td>
<td>5.1%</td>
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<tr>
<td>OTHER</td>
<td>95%</td>
<td>5%</td>
<td>0%</td>
<td>0.4%</td>
</tr>
<tr>
<td>WILL</td>
<td>94%</td>
<td>5%</td>
<td>0%</td>
<td>7.0%</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>86%</strong></td>
<td><strong>9%</strong></td>
<td><strong>5%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>

### AFTER CORDON PRICING

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</thead>
<tbody>
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<td>16%</td>
<td>33%</td>
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<td>COOK</td>
<td>82%</td>
<td>12%</td>
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</table>
Simulation Comparisons

- Demand by hour for all Trips to Downtown
Simulation Comparisons

- Demand by hour for Auto Mode Trips
Simulation Comparison

- Demand for non-downtown auto trips by hour

![Graph showing demand for non-downtown auto trips by hour. The graph compares 'Before' and 'After' scenarios.](graph.png)
Simulation Discussion

- Representation of complex response to cordon pricing policy
  - Desired effect of decreased auto-demand during peak periods to downtown
  - Effects continue after pricing ends – due to trip chain effect (no autos for secondary trips)
  - Side effect of increased auto-demand overall

- Simplified models with aggregate results
  - No feedback, learning, etc. in LOS representation
  - Reevaluate when ADAPTS completed
  - Need to observe results at disaggregate geographies
Conclusion
Discussion and Conclusions

- ADAPTS framework represents dynamics of activity planning
  - Dynamic activity generation (when completed)
  - Conditional attribute planning (from plan order model)

- Plan order model sets when planning decisions made
  - Correlated responses give more realistic planning order
  - Linked directly to key policy variables
  - Allows conditional attribute planning

- Flexible activity scheduling with conflict resolution
  - No predetermined order of activities entering schedule
Discussion and Conclusions

- Promising initial simulation results
  - Demonstration of trip-chaining effect
  - Demand shift due to pricing

- Future work:
  - Integration of plan horizon responses to simulation time
  - Development of rest of attribute models
  - Test impact of planning behavior changes on travel demand
  - Link to traffic simulation/assignment
Thank You!

Questions?