Microsimulating Activity & Travel by Person & Household Agents

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Presentation Outline

- Research Objectives: Long Term vs. Short Term
- Major Components of the Model
- The Theoretical Model
- The Operational Model
  - Program class structure
  - Construction of schedules
  - Mode choice
  - Ridesharing
  - Auto transactions
- Model Validation
- Next Steps
Research Objectives

- Long Term Objectives
  - Create a fully dynamic, integrated microsimulation model of household activity scheduling with interactive household agents
  - Integrated with ILUTE

- Short Term Objectives
  - Operational 24-hour activity scheduling model for use in policy analysis in the Greater Toronto Area (GTA)
The ILUTE Modelling Framework

Regional Economics
Government Policies
Transport System

Demographics
Land Use
Location Choice
Auto Ownership
Activity/Travel & Goods Movement
Dynamic Traffic Assignment Model

Flows, Times, etc.
External Impacts

Focus of today’s presentation
Theoretical Model - Major Components

- Household agents
  - Person
  - Household
- Household resources
  - Time, Money, Vehicles
- The “episode”
  - Activity episodes, Travel episodes
- The “project”
- The “project agenda”
- The “person schedule”

Papers presenting the conceptual model:


Object-Oriented Programming

• The model is being developed within the OOP paradigm (C++)

• OOP ideal for microsimulation applications

• Model design focuses on definition of the objects which exist & interact within the system
Partial View of Relationships Among System Objects

- Vehicle
  - Schedule
- Person 1
  - Agenda
  - Schedule
- Household
  - Agenda
  - Schedule
- Person 2
  - Agenda
  - Schedule
- Dwelling Unit
- Zone
- Worker
- Building
- Firm
- Job
- Agenda
Definitions: Activity

Activity: The various ways in which we spend our time (work, school, shopping, watching TV, …)

In our model, activity is actually a rather loose concept (e.g., “activity” *per se* does not exist as a class within the model.)
## Typology of Activity Commitments

<table>
<thead>
<tr>
<th></th>
<th>On-Going Commitment</th>
<th>One-Time Commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outside the</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Household</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Within the</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Household</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>With Oneself</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Definitions: Episode

Episode: A specific instance of participating in a given activity; at a minimum, episodes have:
- type
- location
- start time
- duration (end time)
- mode

The episode is a primary unit of analysis (class/object) in our model. Two sub-classes exist:
- activity episode
- travel episode
Definitions: Primary Episode

**Primary Episode:** A special type of episode that may be sub-divided into smaller episodes.

At the moment, only work and in-home activities possess primary episodes.

Shopping might also benefit from this concept.
Definitions: Project

Project: A set of activities, logically connected by a common goal or other organizing principle

e.g.: a dinner party; a home renovation project; work; education; child-rearing; ....

The primary unit of analysis (class) in the model.

Note that both persons and households may have projects.
Conceptual Potential of Projects

It is hoped that we can *encapsulate* behavior within the project class in a way that will allow us to model very complex behavior in a manageable manner.

That is, each project needs only to “know about” its own activities -- can therefore decompose the complexity of daily activities into separate, more “bite size pieces” in a theoretically defensible way.

Projects interact with one another through the scheduling process, and through competition for household (and personal) resources.
Definitions: Agenda

**Agenda:** The agenda is the list of activity episodes which might be engaged in by the project within the current planning period.
Knowledge Base
- Current task list management rules
- Information concerning resources
- Project utility level, completion level, etc.
- Project history
- Other information

Task Manager
- List of activities defining the project
- Control of project execution / activity episode generation

Agenda
- Episode 1
- Episode 2
- Episode 3
- ...

The Project

Suggested episodes for provisional scheduling

Requests for episode modification options & implications; next set of episodes for provisional scheduling

Information updates

Changes to project management rules
Definitions: Schedule

**Schedule:** A planned, feasible sequence of activity and travel episodes that collectively fill the day.

Persons and vehicles have schedules; households do not.

A primary objective of the model is to determine the schedule for each person in the household.

When actually executed, the schedule represents the person’s **activity pattern** for the day.

**Trip chains** or **tours** are the natural outcome of sequences of out-of-home activity episodes being scheduled “back to back”.
Scheduling Episodes

Project 1
- episode 1.1
- episode 1.2
- ...

Project 2
- episode 2.1
- episode 2.2
- ...

Project N
- episode N.1
- episode N.2
- ...

Day 1  Day 2  Day 3  Day 4  Day 5  Day 6  Day 7
Joint Activities

Joint Shopping Activity:
Duration: 2 hrs
Location: The Mall

Search for feasible joint time slot
Serve Dependents

Child’s Schedule
- At-Home
- Daycare
- At-Home

Adult 1 Schedule
- At-Home
- Work
- At-Home

Adult 2 Schedule
- At-Home
- Shopping

Take child to/from daycare
Relationship Between Persons & Household

- Requests for resources, availability for tasks
- Allocation of resources, assignment of tasks
Vehicle Allocation, 1-Car Household

Time

Person 1  Person 2  Car 1

Request for car
An Operational Agent-Based Activity/Travel Scheduling Model

The Travel/Activity Scheduler for Household Agents (TASHA) is an operational activity/travel scheduler for the Greater Toronto Area (GTA).

- Multi-agent: persons and households
- Microsimulation
- Developed using ordinary travel survey data

References:


Features of the Theoretical Model

- Long term schedule (e.g., 1 week)
- Dynamic schedule
- Interactive agents
- Detailed project types
- Fully microsimulated (i.e., 100% population)
- Integrated with other household decisions
Features of the Operational Model

- 24-hour schedule
- Semi-dynamic schedule
- Interactive agents
- Broad project and episode types
- Microsimulation of 5% sample
- Sequential household decisions
  - Residential location, work location, auto ownership are inputs
  - Determine the schedule based on auto-drive travel times
  - Mode choice is done after the schedules are complete

Many of the restrictions in the operational model stem from the use of data from a conventional trip-based survey to develop the model.
TASHA Class Structure

World

- Households
- Episode Distributions
- Spatial Representation

Persons

- Person Projects
- Household Projects

Person Schedule
- Travel Episodes
- Individual Activity Episodes
- Joint Activity Episodes

Person Project Agenda
- Individual Activity Episodes

Household Project Agenda
- Travel Time Matrices
- Distance Matrix
- Zones
Project Types

Person-Level Projects
- Work Project
- School Project
- Shopping Project
- Other Project

Household-Level Projects
- Joint Shopping Project
- Joint Other Project
- Serve Dependent Project
Treatment of Time

- For scheduling, 5 minute time increments
  - start times
  - durations/travel times
- For trip assignment, 4 time periods
  - 0600-0859
  - 0900-1459
  - 1500-1859
  - 1900-0559

(EMME/2 currently used for trip assignment, but any network assignment/simulation model could, in principle, be used)
Current Model Structure

- Scheduler (auto times only)
- Tour-Base Mode Choice & Vehicle Allocation
- Aggregate Trips by Time Slot
- Static Assignment by Time Slot

Eventual Model Structure

- Combined Scheduling Tour-Based Mode Choice & Vehicle Allocation
- Dynamic Routing & Assignment
Construction of Schedules - Methodology

- Randomly generate activity episodes
  - Frequency, start time, duration, location
- Insert episodes into project agendas
- Construct person schedules
  - Insert episodes in order of priority
  - Joint episodes added simultaneously
  - Travel episodes added (assuming auto drive)
  - Trip chains emerge naturally
- Clean up the schedule
- Identify trip chains
- Run chain-based mode choice model
Activity Episode Frequency, Start Time and Duration Generation

(a) Draw activity frequency from marginal PDF
(b) Draw activity start time from feasible region in joint PDF
(c) Draw activity duration from feasible region in joint PDF
Inserting Activity Episodes Into the Project Agenda

- Shopping 1 – No conflict
- Shopping 2 – Partial overlap with one episode
- Shopping 3 – Insert between 2 episodes

= “Gap” in Project Agenda

= Activity Episode

Shopping 1 | Shopping 3 | Shopping 2

Time

Shopping Project Agenda
### Moving Activity Episodes from Project Agendas to the Person Schedule

<table>
<thead>
<tr>
<th>Work Project</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>School Project</td>
<td></td>
</tr>
<tr>
<td>Other Project</td>
<td>Other</td>
</tr>
<tr>
<td>Shopping Project</td>
<td>Shop 1, Shop 2</td>
</tr>
</tbody>
</table>

| Person Schedule   | At-home, Work, Shop 1, Other, Shop 2, At-home |

- = “Gap” in Project Agenda
= Activity Episode
= Travel Episode
Inserting an Episode into a Schedule
Splitting a primary work episode with a work-business episode

Prior Case

Becomes

Primary Work Event 1

Episode 1a  New Episode  Episode 1b

Extension to episode 1b’s duration to maintain total primary work event time, given the need to travel to/from the work-business episode location.

Gross duration to be inserted

Travel Episode
Inserting a new Episode, Prior Location Different from Posterior Location

(a) Schedule prior to inserting new episode

(b) Schedule after inserting new episode

New Travel Episode

Existing travel episode deleted by new insertion

Existing Travel Episode
“Chaining” Episodes Together

(a) Schedule with residual home episode (from previous figure)

(b) Schedule after “chaining” episodes together
Mode Choice Model

- Applied sequentially, based on the trip chains from the activity schedule model
- Chain-based
- Random utility formulation, with direct calculation of utilities

Papers documenting the model:


Mode Choice Model Structure

Chain \( c \)
Trips 1, \ldots, \( T_c \)

Auto-Drive Chain
All trips made by auto-drive mode

Non-Drive Chain

Trip 1 Mode
Trip 2 Mode
\ldots
Trip \( T_c \) Mode
Mode Choice
Decision Tree
with Sub-Chain

Chain c:
1. Home-Work
2. Work-Lunch
3. Lunch-Meeting
4. Meeting-Work
5. Work-Home

Drive Option for Chain c

Non-drive Option for Chain c

Sub-Chain s:
2. Work-Lunch
3. Lunch-Meeting
4. Meeting-Work

Drive for Sub-chain s
m2 = drive
m3 = drive
m4 = drive
m5 = drive

Non-drive for Sub-chain s
m2 = drive
m3 = drive
m4 = drive

mN = mode chosen for trip N
The mode choice model dynamically allocates household vehicles to drivers in cases of conflicts, based on maximizing overall household utility.
Random Utility Formulation

- Utility of a trip \( t \) by mode \( m \):
  \[
  U_{mt} = V_{mt} + \varepsilon_{mt}
  \quad \text{m } \in \text{ feasible modes}
  \]

- Utility of a trip chain \( c \) with by a set of modes \( M \):
  \[
  U_{Mc} = \sum_t V_{mt} + \sum_t \varepsilon_{mt}
  \quad \text{M } \in \text{ feasible mode combinations}
  \]

- For simple chains \( M \) includes:
  - All-drive chains
  - All-bicycle chains
  - Non Personal Vehicle (NPV) chains
Random Utility Formulation

- Standard RUM Assumption:
  \[ U_{M^*c} \geq U_{Mc} \quad \forall M,M^* \in \text{feasible mode sets; } M^* \neq M \]

- In our microsimulation framework we:
  - Randomly simulate error terms
  - Directly compare utilities for individual trip chains
  - Explicitly choose the maximum utility set of modes

- Replicate many times to result in probability that a set of modes is chosen for that trip chain
**Joint Trip** - A joint trip is a trip in which more than one household member travel together to or from a joint activity. This can either be a rideshare trip (by car), taking transit together, walking together, etc.

**Serve Passenger Trip** - A trip made by one member of a household for the purpose of transporting another member to their desired activity. A serve passenger trip may include a passenger (e.g. the trip to drop someone off), or may not include a passenger (e.g. the return trip home after dropping someone off).

**Pure Joint Tour** – A joint tour is a tour in which more than one household member travel together to or from at least one joint activity. A pure joint tour occurs when all of the activities on the tours of multiple household members are joint activities. These household members travel together to and from joint activities, and all of these household members make the same trips on the entire tour, at the same times to the same locations. Mode choice for pure joint tours is assumed to be a joint decision, simultaneously determined for all joint activity participants.

**Partial Joint Tour** - A partial joint tour is possible when some but not all of the activities on the tours of multiple household members are joint activities. A partial joint tour occurs when some but not all of the trips in each of these household members’ tours, accessing or egressing from the joint activity, are at the same time, have the same origin and destination, and are by a shared mode.

**Pure Serve Passenger Tour** - A tour made by one household member solely for the purpose of picking up or dropping off another household member. No activities other than “dropping off” or “picking up” are conducted on a pure serve passenger tour.

**En route Serve Passenger Tour** - A tour made by one household member that includes at least one serve passenger trip, but also includes other activities before or after the serve passenger trip. For example, a tour in which a parent drops off a child at school on the way to work would be considered an en route serve passenger tour.
# Tour-Based Mode Choice Model Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Coefficient</th>
<th>Lik. Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>c-tr_n_dr</td>
<td>Mode specific constant for transit all-way</td>
<td>-0.166</td>
<td>18.46</td>
</tr>
<tr>
<td>c-walk</td>
<td>Mode specific constant for walk</td>
<td>-0.304</td>
<td>28.96</td>
</tr>
<tr>
<td>c-ridesh</td>
<td>Mode specific constant for rideshare (for joint trips)</td>
<td>0.835</td>
<td>72.40</td>
</tr>
<tr>
<td>c-pass</td>
<td>Mode specific constant for auto passenger</td>
<td>-2.385</td>
<td>527.0</td>
</tr>
<tr>
<td>atime</td>
<td>Auto in-vehicle travel time (min)</td>
<td>-0.075</td>
<td>167.2</td>
</tr>
<tr>
<td>tivtt</td>
<td>Transit in-vehicle travel time (min)</td>
<td>-0.029</td>
<td>94.7</td>
</tr>
<tr>
<td>twalk</td>
<td>Walk travel time including walk access to/from transit (min)</td>
<td>-0.064</td>
<td>1263.5</td>
</tr>
<tr>
<td>twait</td>
<td>Transit wait time (min)</td>
<td>-0.145</td>
<td>267.8</td>
</tr>
<tr>
<td>travelcost</td>
<td>Travel cost ($1996 Canadian)</td>
<td>-0.065</td>
<td>28.7</td>
</tr>
<tr>
<td>pkcost</td>
<td>Parking cost ($1996 Canadian)</td>
<td>-0.302</td>
<td>314.2</td>
</tr>
<tr>
<td>dpurp_shop_d</td>
<td>=1 if trip purpose = shopping (drive mode); = 0 otherwise</td>
<td>0.993</td>
<td>174.0</td>
</tr>
<tr>
<td>dpurp_sch_d</td>
<td>=1 if trip purpose = school (drive mode); = 0 otherwise</td>
<td>-1.181</td>
<td>302.1</td>
</tr>
<tr>
<td>dpurp_oth_d</td>
<td>=1 if trip purpose = other (drive mode); = 0 otherwise</td>
<td>0.593</td>
<td>116.7</td>
</tr>
<tr>
<td>dest_pd1_w</td>
<td>=1 for walk trips destined for downtown Toronto; = 0 otherwise</td>
<td>0.897</td>
<td>114.3</td>
</tr>
<tr>
<td>intrazonal_t</td>
<td>=1 for an intrazonal trip for transit all-way mode; = 0 otherwise</td>
<td>-2.962</td>
<td>299.9</td>
</tr>
<tr>
<td>adjzone_t</td>
<td>=1 for an adjacent zone for transit all-way mode; = 0 otherwise</td>
<td>-1.016</td>
<td>142.2</td>
</tr>
<tr>
<td>age11_15_p</td>
<td>=1 if age 11-15 (passenger mode); =0 otherwise</td>
<td>0.954</td>
<td>61.3</td>
</tr>
<tr>
<td>Etrip_par</td>
<td>Scaled variance for the trip specific error term</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Num Observations: 19335  
Num Parameters: 17  
Log Likelihood L(â): -5035.87  
Log Likelihood No Parameters L(0): -17434.8  
-2[L(0)-L(â)]: 24797.8  
rho^2: 0.7112  
Adjusted rho^2: 0.7102  
Number of Observations in which observed mode never chosen: 166
**Table 2.8 Prediction Success Table for the Estimated Model (Trips)**

<table>
<thead>
<tr>
<th>Observed Mode</th>
<th>Predicted Mode</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Drive</td>
<td>Transit</td>
</tr>
<tr>
<td>Drive</td>
<td>11054</td>
<td>448</td>
</tr>
<tr>
<td>Transit</td>
<td>487</td>
<td>2313</td>
</tr>
<tr>
<td>Walk</td>
<td>122</td>
<td>252</td>
</tr>
<tr>
<td>Rideshare</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Passenger</td>
<td>109</td>
<td>125</td>
</tr>
<tr>
<td>Total</td>
<td>11771</td>
<td>3139</td>
</tr>
</tbody>
</table>

**Table 2.9: Prediction Success Table for the Estimated Model (% of Total Trips)**

<table>
<thead>
<tr>
<th>Observed Mode</th>
<th>Predicted Mode</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Drive</td>
<td>Transit</td>
</tr>
<tr>
<td>Drive</td>
<td>57.2%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Transit</td>
<td>2.5%</td>
<td>12.0%</td>
</tr>
<tr>
<td>Walk</td>
<td>0.6%</td>
<td>1.3%</td>
</tr>
<tr>
<td>Rideshare</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Passenger</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Total</td>
<td>60.9%</td>
<td>16.2%</td>
</tr>
</tbody>
</table>

**Table 2.10: Prediction Success Table for the Estimated Model (% of Observed Mode)**

<table>
<thead>
<tr>
<th>Observed Mode</th>
<th>Predicted Mode</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Drive</td>
<td>Transit</td>
</tr>
<tr>
<td>Drive</td>
<td>94.5%</td>
<td>3.8%</td>
</tr>
<tr>
<td>Transit</td>
<td>15.6%</td>
<td>74.2%</td>
</tr>
<tr>
<td>Walk</td>
<td>9.4%</td>
<td>19.4%</td>
</tr>
<tr>
<td>Rideshare</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Passenger</td>
<td>28.3%</td>
<td>32.5%</td>
</tr>
<tr>
<td>Total</td>
<td>60.9%</td>
<td>16.2%</td>
</tr>
</tbody>
</table>
Location Choice

- Locations are unknown for all episodes except usual place of work and school
- Currently simple (logit) location destination choice models are used based on home or work location
- Must do better!
- Carrasco looking at spatial aspects of social networks
The predictive performance of the TASHA model has been tested by means of:

- **Verification** of its ability to reproduce 1996 base year activity schedules.
- **Validation** of its ability to predict observed 2001 activity schedule.
## Some Summary Statistics

### 1996 Test:

<table>
<thead>
<tr>
<th>Activity</th>
<th>TASHA-Total Freq</th>
<th>TASHA-% Freq</th>
<th>TTS-Total Freq</th>
<th>TTS - % Freq</th>
<th>TASHA-AvgDist-km</th>
<th>TTS-AvgDist-km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>182113</td>
<td>45.53</td>
<td>187254</td>
<td>45.2</td>
<td>8.68</td>
<td>8.54</td>
</tr>
<tr>
<td>Shopping</td>
<td>32929</td>
<td>8.23</td>
<td>35679</td>
<td>8.61</td>
<td>5.67</td>
<td>4.83</td>
</tr>
<tr>
<td>Others</td>
<td>59671</td>
<td>14.92</td>
<td>64290</td>
<td>15.52</td>
<td>7.74</td>
<td>7.39</td>
</tr>
<tr>
<td>School</td>
<td>29425</td>
<td>7.36</td>
<td>30500</td>
<td>7.36</td>
<td>6.51</td>
<td>5.05</td>
</tr>
<tr>
<td>Work</td>
<td>95838</td>
<td>23.96</td>
<td>96574</td>
<td>23.31</td>
<td>12.76</td>
<td>12.04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>399976</strong></td>
<td><strong>45.93</strong></td>
<td><strong>414297</strong></td>
<td><strong>45.2</strong></td>
<td><strong>8.68</strong></td>
<td><strong>8.54</strong></td>
</tr>
</tbody>
</table>

### 2001 Test:

<table>
<thead>
<tr>
<th>Activity</th>
<th>TASHA-Total Freq</th>
<th>TASHA-% Freq</th>
<th>TTS-Total Freq</th>
<th>TTS - % Freq</th>
<th>TASHA-AvgDist-km</th>
<th>TTS-AvgDist-km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>266345</td>
<td>45.48</td>
<td>286125</td>
<td>45.19</td>
<td>9.21</td>
<td>9.21</td>
</tr>
<tr>
<td>Marketing</td>
<td>46414</td>
<td>7.93</td>
<td>54550</td>
<td>8.62</td>
<td>5.87</td>
<td>5.47</td>
</tr>
<tr>
<td>Others</td>
<td>84914</td>
<td>14.5</td>
<td>100452</td>
<td>15.86</td>
<td>7.97</td>
<td>8.93</td>
</tr>
<tr>
<td>School</td>
<td>42518</td>
<td>7.26</td>
<td>44190</td>
<td>6.98</td>
<td>6.42</td>
<td>5.45</td>
</tr>
<tr>
<td>Work</td>
<td>145388</td>
<td>24.83</td>
<td>147860</td>
<td>23.35</td>
<td>13.56</td>
<td>13.04</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>585579</strong></td>
<td><strong>45.48</strong></td>
<td><strong>633177</strong></td>
<td><strong>45.2</strong></td>
<td><strong>9.21</strong></td>
<td><strong>9.21</strong></td>
</tr>
</tbody>
</table>
1996 & 2001 Validation: Activity Episode Frequency by Time of Day
1996 & 2001 Validation: Activity Episode Durations by Time of Day

Figures 2.15 to 2.19

Activity Duration: Work
Activity Duration: School
Activity Duration: Others (Home Stay within Activity Chain)
Activity Duration: Shopping
Next Steps

- The validated model will be used to test the impacts on GTA travel behaviour of a variety of land use and transport network options (about to start)
- Develop improved models of non-work/school activity location choice
- Develop schedule- & policy-sensitive models of activity episode generation (underway)
- Tie TASHA to a model of household auto ownership (underway)
- Integrate mode choice model within the scheduler
- Extend to a full week?
- Incorporate panel survey results
Panel Survey

We have recently completed a 3-year panel survey to gather detailed information about household activity scheduling behaviour.

Approx. 270 households (Wave 1) in each of Toronto & Quebec City.

Wave 1 (2002-03):
- 1 week activities per person 16+ years old.
- CHASE survey method in Toronto; paper diary in Q.C.

Wave 2 (2003-04):
- 2-day paper activity diary + SP experiments

Wave 3 (2004-06):
- 2-day paper activity diary
- Routine, skeleton schedule” gathered prior to diary

“TASHA/2” will incorporate many findings from this survey.
Thank you!
Any questions?