Opportunities and Challenges With The Micro-simulation of Spatial Activity Systems

by

JD Hunt, University of Calgary

SOLUTIONS Project Conference
Cambridge, UK
15 December 2004
Overview

- Nature of Micro-simulation
- Promise of Micro-simulation
- Challenges of Micro-simulation
- Examples
  - Calgary Commercial Movements Model
  - Oregon Generation 2 System
  - Business Establishments Testbed
- Conclusions
Nature of Micro-simulation

- Consider system of multiple agents
- Determine states of individual agents
  - Over time
  - Representing actions and reactions of individual agents
  - Accounting for interactions among agents
- Aggregate to establish emergent system behaviour
- Technique, not Theory

Examples include:
- Traffic micro-assignment
- Tour-based household travel micro-simulation
- Cellular automata
Determining States

- Behavioural component
- Range of techniques
  - Transition Rules
  - Monte Carlo with Sampling Distribution
  - Monte Carlo with Behavioural Choice Model
  - Durations (continuous values)
  - Learning
  - Searching
- Time-based or Event-based
Determining States

Transition Rule

if now: a

then later: b
Determining States

Monte Carlo with Sampling Distribution

observed
Determining States

Monte Carlo with Behavioural Choice Model

\[ P_a = \frac{e^{\lambda U_i}}{\Sigma_i e^{\lambda U_i}} \]
Determining States

Durations: Monte Carlo with Sampling Distribution

duration = t

![Diagram showing a bell curve and a graph with a random number generator outputting a value t.](image)
Promise of Micro-simulation

- Greater realism and accuracy
  - Finer resolution in representation of influences
  - More complete accounting and representation of specific constraints
  - Direct representation of variations in sensitivities
  - Reproducing processes, not seeking equilibrium
- Reduced computational burden
- Flexibility in aggregation of results
- Comparative ease in understanding
  - Greater confidence
  - Object-oriented design
Challenges with Micro-simulation

- Variation in results
  - Because random component explicit
  - Consistent with analyst uncertainty, not temporal variation in inputs; potential misinterpretation?
  - Need multiple runs to seek expectations, increasing computation burden - beware ‘fixed-seed quick fix’
  - Uncertainty problematic for decision-makers
- Limited knowledge about actual processes
- Unreasonable expectations
Challenges with Micro-simulation

- Richer Results
  - False sense of understanding
  - Less skepticism, overconfidence in results
  - Overlook problems

- Calibration problematic
  - Real world only one possible outcome
  - Little on path dependencies and impacts of starting conditions

- ‘Hard-wired’ vs ‘Emergent’ results in aggregate
Examples

- Calgary Commercial Movement Model
- Oregon Generation 2 System
- Business Establishment Testbed
Commercial Vehicle Movements

- Vehicles operated for commercial purposes
- As opposed to household, personal movements
- Includes ‘non-commercial’ non-household purposes (government, not-for-profit)
- Comprise 10-15% of total urban traffic
Some Examples

Commercial
- Hauling freight for a company
- Service workers visiting clients
- Sales meetings
- Mail
- Delivering parcels

Personal
- Travel to work
- Travel to school
- Shopping
- Leisure trips
- Social visits
Tour-based Micro-simulation

- Considers tours rather than individual trips
- Micro-simulation of each tour
  - Monte Carlo techniques
  - Choice models for some sampling distributions for decisions
- Uses additional information for decisions
  - Full-tour conditions
  - Location of establishment (tour-base)
  - Work-shift influences
  - Simulates each trip as tour progresses
- Closer to reality
  - A number of clients scattered throughout city
  - Efficient businesses will service them in tours
Micro-simulation Process

- Tour Generation
  - Vehicle and Tour Purpose
    - Tour Start
      - Next Stop Purpose
        - Next Stop Location
          - Stop Duration

Iterative
Goods / Service

Establishment

Client

Return to Establishment

Client

Client

Lunch

Other
Stop Duration
Private Service - Service - Light
Estimation ... then Calibration

- Estimate model coefficients using choice data
- Update alternative specific constants using aggregate data
  - Trip tables from Commodity Flow Survey
  - Link counts
  - Screenline and cordon counts
- Aggregate Targets
  - Trips per tour (tour length)
  - Number of tours by vehicle type and tour purpose
  - Number of stop by commercial model segment
  - Stop locations by vehicle type and geographic sector
  - Intra-sector trips by vehicle type
  - Screenline crossings by time period
Calibration

Light Vehicle Destination Split

Target
Run 20
Run 58
Micro-simulation Process

- Tour starting in zone 340 (Central Industrial) AM Peak
- Light vehicle; service tour
- Current time:
  - Service, 211 (Stampede)
  - Service, 209 (Apartment)
  - Other, 2205 (Marathon rest.)
  - Service, 2312 (North Hill Mall)
  - Return to establishment, 340
Operation

- Works in conjunction with personal transportation model (PTM)
  - Running in parallel
  - Trip tables loaded jointly
  - Congested times fed back
  - Iterations to convergence
Operation

- Commercial Movements Model (micro-simulation)
- PTM (EMME/2)

- Base Information
  - Run of model
    - Updated personal trip tables
  - Run of process
    - Updated commercial vehicle trip tables

- Updated travel times
- Re-assignment of trip tables
Model network loading of light vehicle flows
Model network loading of heavy vehicle flows

- less in CBD;
- more in industrial areas
- little on non-truck routes
Calgary Conclusions

- Tour-based micro-simulation approach used here
  - Successful
  - Provides direct representation of trip-chaining impacts
  - Includes service delivery
  - Well beyond ‘freight only’ and ‘large heavy vehicle’ limitations
- Useful planning tool for
  - Including commercial movements and their impacts on system
  - Assessing impacts of transportation policy and infrastructure development on commercial sectors
Calgary Conclusions

- Micro-simulation process stable
- Still an equilibrium model in aggregate, with demand and supply interaction to consistency
- Can integrate with aggregate, equilibrium model
- Extensive modular expansion possible; example is stop duration module
  - Rudimentary sampling from observed distribution
  - ‘weak link’ in micro-simulation
  - Misses influences
    - Stop order
    - Previous stop history
    - Time of day
  - More complete representation warranted & feasible
Calgary Acknowledgements

• Funding
  • City of Calgary
  • City of Edmonton
  • Province of Alberta
  • Natural Sciences and Engineering Research Council of Canada
  • Social Sciences and Humanities Research Council of Canada

• Participation
  • Kevin Stefan, Karen Tsang
  • Ali Farhan, Dianne Atkins, Paul McMillan
  • Alan Brownlee, Bob Ishani, Ian Bakker
Examples

- Calgary Commercial Movement Model
- Oregon Generation 2 System
- Business Establishment Testbed
Generation 2 Structure
Modules and Interactions

- Data store
  - Regional economics and demographics
  - Production allocations and interactions
  - Household allocations
  - Land development
  - Household travel
  - Commercial movements
  - Transport loadings
Generation 2 Structure
Household Allocations

- regional economics and demographics
- production allocations and interactions
- household allocations
- land development
- household travel
- commercial movements
- transport loadings

Data store
Household Allocations
Processes and Sub-modules

- Synthetic population
  - Births
  - Aging
  - Career
  - Deaths

- Leave household
  - Income
  - Move to find work

- New household pool
  - Income
  - Location choice
  - Jobs
  - Dwelling type & size

- Moving pool
  - Yes
  - No
  - In migrating households

- Updated synthetic population
  - Next year

Census STF
Census PUMS
Population synthesizer
HA Location Choice Model Structure

- workplace dependency
- stay
- move
- leave
- dwelling type
  - zone
  - floorspace quantity
  - grid cell
### Household Allocations Example

<table>
<thead>
<tr>
<th>1 auto</th>
<th>26560/yr</th>
<th>TAZ 1550</th>
</tr>
</thead>
<tbody>
<tr>
<td>64 yo</td>
<td>Female</td>
<td>no job</td>
</tr>
<tr>
<td>30 yo</td>
<td>Male</td>
<td>empl ft</td>
</tr>
<tr>
<td>1 auto</td>
<td>26560/yr</td>
<td>TAZ 181</td>
</tr>
<tr>
<td>66 yo</td>
<td>Female</td>
<td>no job</td>
</tr>
<tr>
<td>32 yo</td>
<td>Male</td>
<td>empl ft</td>
</tr>
</tbody>
</table>
# Household Allocations Example

<table>
<thead>
<tr>
<th>5 autos</th>
<th>31805/yr</th>
<th>TAZ 3130</th>
<th>Age</th>
<th>Gender</th>
<th>Employment</th>
<th>Occupation</th>
<th>Education</th>
<th>School Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>42 yo</td>
<td>Male</td>
<td>empl ft</td>
<td>7 NonOfc</td>
<td>bachlrs</td>
<td>not school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43 yo</td>
<td>Female</td>
<td>no job</td>
<td>no occupation</td>
<td>some college</td>
<td>not in school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 yo</td>
<td>Female</td>
<td>empl ft</td>
<td>7 NonOfc</td>
<td>HighSch</td>
<td>not school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 yo</td>
<td>Female</td>
<td>emp pt</td>
<td>7 NonOfc</td>
<td>10th grd</td>
<td>in school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 yo</td>
<td>Female</td>
<td>no job</td>
<td>no occupation</td>
<td>no grds</td>
<td>in school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 autos</td>
<td>33213/yr</td>
<td>TAZ 3130</td>
<td>Age</td>
<td>Gender</td>
<td>Employment</td>
<td>Occupation</td>
<td>Education</td>
<td>School Status</td>
</tr>
<tr>
<td>44 yo</td>
<td>Male</td>
<td>empl ft</td>
<td>7 NonOfc</td>
<td>bachlrs</td>
<td>not school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45 yo</td>
<td>Female</td>
<td>no job</td>
<td>no occupation</td>
<td>some college</td>
<td>not in school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 yo</td>
<td>Female</td>
<td>emp pt</td>
<td>7 NonOfc</td>
<td>HighSch</td>
<td>in school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 yo</td>
<td>Female</td>
<td>no job</td>
<td>no occupation</td>
<td>2nd grd</td>
<td>in school</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Generation 2 Structure
Land Development

- regional economics and demographics
- transport loadings
- commercial movements
- household travel
- production allocations and interactions
- household allocations
- land development

[Diagram showing data store connected to various components]
Generation 2 Structure
LD Treatment of Space

works at cell level
Generation 2 Structure
Household Travel

- Regional economics and demographics
- Production allocations and interactions
- Household allocations
- Land development
- Commercial movements
- Transport loadings
- Data store

PT: Household travel
Household Travel Processes and Sub-modules

- Synthetic population in zone
  - Activity pattern ‘word’
  - Activity durations
  - Home-based tour list
  - Work-based tour list

- Trip mode
  - Trip start time
  - Stop cell
  - Intermediate stop zone
  - Intermediate stops list
  - Home-based primary destination zone
  - Work-based primary destination zone

- Trip end time
- Trip list
- Tour mode
- Intermediate stop pattern
- Dependent tour mode

- Home-based primary destination zone
- Tour list
- Trips start time
- Trips end time
Transport Loadings
Processes and Sub-modules

- Trip list
- Public transport trip list
- Once for each trip in list
- Optimal strategies path selection
- Minimum path for trip
- Updated link volumes
- Expected times and costs for trips
- Expected times and costs for links
- Updated times and costs for links
- Updated times and costs for trips
- Equilibrium assignment
- Resolve into trip tables by time period
- Private vehicle trip list
- Once for each trip in list
- Personal travel module for same year
- Modules for next year
- Once for each trip in list
Oregon Conclusions

- Work is on-going
- Aggregate equilibrium constraints appropriate
- Extensive modular expansion helpful
  - Allowed staged developed
  - ‘Transition Model’ available for use
- Data and Computing Requirements Difficult
  - Synthesis unavoidable
  - Substantial Parallel Processing
  - Multiple Runs Straining Matters
- Behaviour Models Limited
  - Logit Choice with Full Information
  - Need to Draw More from Other Areas
    - Psychology
    - Artificial Intelligence
Oregon Acknowledgements

• Funding
  • State of Oregon
  • United States Federal Highway Administration

• Participation
  • John Abraham
  • Rick Donnelly, Tara Weidner, Christi Willisden, Jim Hicks, Carl Batten, Pat Costinett, Susan Hendricks, Bill Davidson, Tim Heier, Joel Freedman, Larry Conrad, Tracey Lauritsen, Paul Waddell
  • Bill Upton, Brian Gregor
Examples

- Calgary Commercial Movement Model
- Oregon Generation 2 System
- Business Establishment Testbed
PECAS & This Research

- Allocation to location ‘grid cell’
- Aggregation of commodity production and consumption utilities, choice of production function
- Allocation of commodity buying and selling to exchange zones based on price at exchange zones and transport disutility to/from exchange zones
- Locate individual BEs
- Replace equilibrium price representation with dynamic price update representation based on excess demand
EA Representation

Input

- Region wide conditions
- Location utilities
- Commodity Prices, Quantities by exchange zones (including floorspace prices and quantities)

Output

- Location of business activities
- Surplus or shortage of floorspace and commodities

Update
Approach - LD Dynamic Behaviour

- Floorspace changes each year
  - simulate decisions for each grid cell based on prices

[Diagram]

- Developer choice
  - No Change
    - Add more of the same
  - Change
    - Redevelop
Reference Case

30% floorspace rent subsidy zones 202, 203, 204
Reference Case

50% development cost subsidy zones 202, 203, 204
Testbed Application – Alternative Policy Test

5

Reference Case

double travel costs everywhere
Testbed Application – Alternative Policy Test

6

Reference Case

new freeway; reduced travel times and costs
Testbed Conclusions

- Provides insights into theory
  - Aggregate patterns emerging from disaggregate rules
    - Central Places
    - Bid-Rent Curves
  - Case of ‘Hard-wired’ Results?
- Useful Practical Implications even though a Testbed
  - Traffic cost increases lead to density increases
  - Radial freeway leads to secondary centres
  - Rent subsidies more effective than development subsidies
- Large Parallel Processing Successful
  - Multiple Runs = Multiple Processors
  - WestGrid a Special Opportunity
- Full System Micro-simulation of businesses and transactions
  - Not practical for beyond testbed - at least now
  - Need Compromise based in some way on aggregations
    - In this case: zonal markets with aggregate supply and demand
Business Establishment Testbed
Acknowledgements

• Funding
  • Natural Sciences and Engineering Research Council of Canada
  • Social Sciences and Humanities Research Council of Canada

• Participation
  • James Khan
  • John Abraham
Conclusions

- Practical reality
  - Starting to deliver on promises
  - Most widespread: traffic micro-simulation
  - Somewhat widespread: demographics, household travel demand
  - Much less widespread for larger scope

- Many Challenges and Opportunities
  - Simplified Behaviour
    - Closer to reality
    - Reduced computation
  - Compromises Required - ‘choose your aggregation’

- Large Teams and Joint Funding
  - Significant data requirements
  - Large computational efforts
  - Multi-disciplinary