Preferred citation style

Agent-based Travel Demand and Traffic Flow Modelling for Mega Cities

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Task
Transport planning models (1)

Are models of

Daily life

reproducing

who is travelling/present

where (location/route/connection)
when
with which vehicle (bike, car, bus, train etc.;)
with whom
for how long
for what purpose
in which daily schedule
Transport planning models (2)

attempt to describe today‘s and model future network conditions consistent with:

- The given supply of capacity through
  - Networks
  - Services provided on them

- The known/assumed amounts of desired travel
- The known correlations between the behavioural dimensions/structures, capacity and the prices for travel

imposing a justifiable set of assumptions on the solution of the resulting fixed point problem (or not)
Transport planning models (3)

Alternatives:

• Direct demand models (spatial regression models)
• Aggregate (static/dynamic) models
• Agent-based dynamic activity – based models (ABM) + static assignment
• Agent-based dynamic travel demand and traffic flow models

Scale:

• Number of agents/segments
• Number of locations/zones
• Number of mode specific links
• Number of mode specific nodes
• Number of modes
• Number of time segments
Transport planning models (4)

Trade-off between:

- Expert time (learning effort)
- Implementation time (data and calibration)
- Time to answer
  - Scenario definition
  - Quality of UE/SUE
  - Computation time for given quality level
- Time to analyse and present the results
- Time to establish trust in the results among the
  - Experts
  - Policy advisers
  - Decision makers
  - Public
- Uses outside transport planning
Thinking about equilibrium
DUE, SO & SUE

Wardrop (1952):

1. The journey times on all the routes actually used are equal, and less than those which would be experienced by a single vehicle on any unused route.
2. The average journey time is a minimum.

Daganzo and Sheffi’s (1977) define SUE for the aggregate case:

“In a SUE network, no user believes he can improve his travel time by unilaterally changing routes.”
Packing problem of the DUE, SO & SUE

Given the

Agent’s daily schedules of predetermined detail

Subject to some

Max F

up to the resolution of the agents, links and facilities

Matching the

Expected elasticities with respect to the generalized costs
Known correlations between the details of the plans
Capacity constraints on the links, services and facilities
Minimum loads for some of the facilities
How to find the SUE in an agent-based approach?
Learning approach of the generic one-day transport model

Competition for slots on networks and in facilities

Mental map

Activity scheduling

$k(t,r,j)_{i,n}$

$q_i \equiv (t,r,j)_{i,n}$
Equilibrium search in MATSim

- Initial schedules

- Simulation of flows on networks and to facilities

- Score (utility) calculation

- (Optimal) Replanning (inc. connection)

- $q_i \equiv (t, r, j)_{i, n}$

- $k(t, r, j)_{i, n}$

- $U_i(t, r, j)_{i, n}$
Following the agents
MATSim: Logic of the co-evolution – Step 0

Agent 1
  Plan 1.1  H-W-H; 8:00, 17:00; C,C;

Agent 2
  Plan 2.1  H-W-H; 8:00, 17:00; C,C;

Agent 3
  Plan 3.1  H-W-H; 8:00, 17:00; C,C;
Co-evolution – Step 1.1 – Simulation/scoring

Agent 1
   Plan 1.1  H-W-H; 8:00, 17:00; C,C;  35

Agent 2
   Plan 2.1  H-W-H; 8:00, 17:00; C,C;  35

Agent 3
   Plan 3.1  H-W-H; 8:00, 17:00; C,C;  35
<table>
<thead>
<tr>
<th>Agent</th>
<th>Plan 1.1</th>
<th>Plan 2.1</th>
<th>Plan 3.1</th>
<th>Plan 3.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H-W-H; 8:00, 17:00; C,C;</td>
<td>H-W-H; 8:00, 17:00; C,C;</td>
<td>H-W-H; 8:00, 17:00; C,C;</td>
<td>H-W-H; 8:15, 17:30; C,C</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Co-evolution – Step 1.3 – After plan selection (best/MNL)

Agent 1
   Plan 1.1    H-W-H; 8:00, 17:00; C,C;           100%

Agent 2
   Plan 2.1    H-W-H; 8:00, 17:00; C,C;           100%

Agent 3
   Plan 3.1    H-W-H; 8:00, 17:00; C,C;            35
   Plan 3.2    H-W-H; 8:15, 17:30; C,C;           New
Co-evolution – Step 2.1 – Simulation/scoring

Agent 1
  Plan 1.1   H-W-H; 8:00, 17:00; C,C;         45

Agent 2
  Plan 2.1   H-W-H; 8:00, 17:00; C,C;         45

Agent 3
  Plan 3.1   H-W-H; 8:00, 17:00; C,C;         35
  Plan 3.2   H-W-H; 8:15, 17:30; C,C;         60
Co-evolution – Step 2.2 – After replanning (1/3)

Agent 1
Plan 1.1  H-W-H; 8:00, 17:00; C,C;  45
Plan 1.2  H-W-H; 8:00, 17:00; B,B;

Agent 2
Plan 2.1  H-W-H; 8:00, 17:00; C,C;  45

Agent 3
Plan 3.1  H-W-H; 8:00, 17:00; C,C;  35
Plan 3.2  H-W-H; 8:15, 17:30; C,C;  60
## Co-evolution – Step 2.3 – After plan selection (best/MNL)

<table>
<thead>
<tr>
<th>Agent 1</th>
<th>Plan 1.1</th>
<th>H-W-H; 8:00, 17:00; C,C;</th>
<th>45</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plan 1.2</td>
<td>H-W-H; 8:00, 17:00; B,B;</td>
<td>New</td>
</tr>
<tr>
<td>Agent 2</td>
<td>Plan 2.1</td>
<td>H-W-H; 8:00, 17:00; C,C;</td>
<td>100%</td>
</tr>
<tr>
<td>Agent 3</td>
<td>Plan 3.1</td>
<td>H-W-H; 8:00, 17:00; C,C;</td>
<td>38%</td>
</tr>
<tr>
<td></td>
<td>Plan 3.2</td>
<td>H-W-H; 8:15, 17:30; C,C;</td>
<td>62%</td>
</tr>
</tbody>
</table>
Co-evolution – Step 3.1 – Simulation/scoring

Agent 1
   Plan 1.1  H-W-H; 8:00, 17:00; C,C; 45
   Plan 1.2  H-W-H; 8:00, 17:00; B,B; 70

Agent 2
   Plan 2.1  H-W-H; 8:00, 17:00; C,C; 45

Agent 3
   Plan 3.1  H-W-H; 8:00, 17:00; C,C; 45
   Plan 3.2  H-W-H; 8:15, 17:30; C,C; 60
## Co-evolution – Step 3.2 – After replanning (1/3)

### Agent 1
- **Plan 1.1**
  - H-W-H; 8:00, 17:00; C,C; 45
- **Plan 1.2**
  - H-W-H; 8:00, 17:00; B,B; 70

### Agent 2
- **Plan 2.1**
  - H-W-H; 8:00, 17:00; C,C; 45

### Agent 3
- **Plan 3.1**
  - H-W-H; 8:00, 17:00; C,C; 45
- **Plan 3.2**
  - H-W-H; 8:15, 17:30; C,C; 60
- **Plan 3.3**
  - H-W-H; 7:30, 17:15; B,B
Co-evolution – Step 3.3 – After plan selection (best/MNL)

<table>
<thead>
<tr>
<th>Agent 1</th>
<th>Plan 1.1</th>
<th>H-W-H; 8:00, 17:00; C,C;</th>
<th>36%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plan 1.2</td>
<td>H-W-H; 8:00, 17:00; B,B;</td>
<td>64%</td>
</tr>
</tbody>
</table>

| Agent 2 | Plan 2.1 | H-W-H; 8:00, 17:00; C,C; | 100% |

| Agent 3 | Plan 3.1 | H-W-H; 8:00, 17:00; C,C; | 45 |
|         | Plan 3.2 | H-W-H; 8:15, 17:30; C,C; | 60 |
|         | Plan 3.3 | H-W-H; 7:30, 17:15; B,B | New |

(The (worst) plan more than memory allows is deleted)
<table>
<thead>
<tr>
<th></th>
<th>Iteration 1</th>
<th>Iteration 2</th>
<th>Iteration 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent 1</td>
<td>35</td>
<td>45</td>
<td>80</td>
</tr>
<tr>
<td>Agent 2</td>
<td>35</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Agent 3</td>
<td>35</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td><strong>35</strong></td>
<td><strong>50</strong></td>
<td><strong>62</strong></td>
</tr>
</tbody>
</table>
MATSim today
Activity scheduling dimensions

Number and type of activities
Sequence of activities

• Start and duration of activity
• Composition of the group undertaking the activity
• Expenditure division
• Location of the activity

• Movement between sequential locations

• Location of access and egress from the mean of transport
  • Parking type
• Vehicle/means of transport
• Route/service
• Group travelling together
• Expenditure division
Current Vickrey-type utility function

\[ U_{plan} = \sum_{i=1}^{n} U_{act,i} + \sum_{i=2}^{n} U_{trav,i-1,i} \]

\[ U_{act,i} = U_{dur,i} + U_{late.ar,i} \]
Modelling Switzerland 2009
2009 MATSim Switzerland: Configuration

During the iterations:

- Optimisation of start time and duration of the activities
- Random location of the activity (with capacity constraint)
- Vehicle/means of transport at sub-tour level
- Optimal routes
- Event-oriented queue-based traffic flow simulation

For a search space of:

- $6.0 \times 10^6$ agents with 11 activity types
- $1.6 \times 10^6$ facilities
- $0.8 \times 10^6$ links
- $24 \times 60 \times 60$ seconds
2009 MATSim Switzerland: Computing time

Graph showing the computing time distribution across iterations.
Quality of the results: Overall counts
Quality of the results: A1 at Winterthur (no transit traffic)
MATSim: A GNU public licence software project
MATSim: A GNU public licence software project

Main partners
- TU Berlin (Prof. Nagel)
- ETH Zürich
- senezon (Dr. Balmer, Dr. Rieser)

Coordination via:
- User meeting
- Conceptual meeting
- Developer meeting
- Code committee
- Regular releases of the code
Current progress: Berlin

Network: 113 000 links
Population: 4,5 million agents
Public Transport: 530 lines, 96 transit vehicle types
Mode choice, Departure time choice, Route choice (car + transit)
Current progress: Switzerland

Network: ~ 1 million links (navigation network)
Population: 8 million
Complete public transport (all trains, buses, trams, cablecars, ...)
Mode choice, Departure time choice, Route choice (car + transit)
Current progress: Switzerland (cont‘d)

Using the model also for site assessment and pedestrian counts
Current progress: Los Angeles

Network: 108,000 links
Population: 10+ million agents
Public transport: Estimated travel times only
Mode choice, Departure time choice, Route choice
Current progress: Singapore

Network: 80 000 links
Population: 5 million
Complete public transport (bus, MRT)
Mode choice, Departure time choice, Route choice (car + transit)
Current progress: Singapore
Schedule detail possibilities (in current stable MATSim)

Number and type of activities
Sequence of activities

- Start and duration of activity
- Composition of the group undertaking the activity (Kowald, Tan, Fourie)
- Expenditure division
- Location of the activity (Horni)

- Movement between sequential locations

- Location of access and egress from the mean of transport
  - Parking search and type (Waraich)
  - Vehicle/means of transport (Ciari)
  - Route/service (Chakirov)
  - Group travelling together (Dubernet, Fourie)

- Expenditure division
Singapore extensions: Allocating work locations
Work location model: motivation and idea

Background:
• Number and location of work activities is crucial for transport modeling
• No enterprise census
• Business registration files problematic for actual work location estimation

Combination of various data sources:
• Boarding and alighting activities at stops
• Land use type and gross plot ratio
• Building footprint
• Mode share
Detection of work activities: start time

Work activities

Home activities

Activity start time

Number of activities

Activity start time

Number of activities

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Applying to public transport smart card records
Scaling by mode shares as observed from travel diary
Distribution to single buildings
Singapore extensions: Interaction between car and buses
Interaction between car and buses (purple)

**Without buslane:**
Adam Rd / PIE

**With buslane:**
Gelyang Rd, aft Sims Way

Source: maps.google.com
Singapore extensions: Value of seating
Value of seating: Morning peak EW line at Tampines

High value of a seat (up to 10 min of additional travel time)
Next challenges: Integration of land use (optimisation)
Next challenges: Integration of land use (optimisation)

ΔPopulation
Δgrowth
ΔPrices
ΔClimat

Travel and land use model

Impacts and Mass flows

GIS^3

Space/mass optimisation

Grammars landscape
Grammars urban design
Grammars infrastructure
Regulation/laws
Sustainability
MATSim @ ETHZ, TU Berlin, FCL, Senozon (past & present)

Prof. Kay Axhausen
Dr. Michael Balmer
Dr. David Charypar
Dr. Nurhan Cetin
Artem Chakirov
Yu Chen
Francesco Ciari
Christoph Dobler
Thibaut Dubernet
Dr. Alexander Erath
Dr. Matthias Feil
Dr. Gunnar Flötteröd
Pieter Fourie

Dr. Christian Gloor
Dominik Grether
Dr. Jeremy K. Hackney
Andreas Horni
Johannes Illenberger
Dr. Gregor Lämmel
Nicolas Lefebvre
Prof. Kai Nagel
Dr. Konrad Meister
Manuel Moyo
Kirill Müller
Andreas Neumann
Thomas Nicolai

Benjamin Kickhöfer
Sergio Ordonez
Dr. Bryan Raney
Dr. Marcel Rieser
Dr. Nadine Rieser
Lijun Sun
Alexander Stahel
Dr. David Strippgen
Michael Van Eggermond
Rashid Waraich
Michael Zilske
Questions?

www.matsim.org
www.ivt.ethz.ch
www.futurecities.ethz.ch
www.senozon.ch
Hypotheses for travel behaviour

- Wages
- Fleet comfort
- Housing consumption
- vtt's et al.
- Energy costs

Activities

Specialisation

Tours

Energy costs

vkm

Elasticity > 0

Elasticity < 0

Energy costs

Network overlap

Local anomie

Number of networks

Network geography

Migration

Professional and personal activity space

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