An agent-based model of travel demand and traffic flow: Recent results with MATSim.

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Thinking about equilibrium
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

upto 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 link and facilities
Minimum loads for some of the facilities
“Activity based approach”
Key points of the critique of equilibrium approaches

• Travel is derived demand, with some exceptions

• The travellers are constrained by their commitments and tool ownership

• Travellers aren’t in equilibrium

• Travellers don’t know all alternatives

• Travellers don’t plan their whole day (week) in advance
Processes suggested tpo model personal daily dynamics

Activity repertoire (t) -> Activity repertoire (t+1)

Activity calendar (t) -> Rescheduling, Execution

Activity schedule (t) -> Networks, Opportunities

Unexecuted activities -> Updates, Innovations

Physiological needs, Commitments, Desires, Pending activities

Scheduling

Mental map (t) -> Mental map (t+1)

Networks, Opportunities
Processes suggested for personal long-term dynamics

(Life) goals (t) ................................. (Life) goals (t+1)

Projects (t) [commitments]

Projects (t) 

Planning, Negotiation

Definition of „Self“
Desires
Pending projects

Paper sequence (t)

Replanning, Execution

Unexecuted projects

Markets and networks

Personal world (t) ................................. Personal world (t+1)

Planning,
Negotiation

Updates, Innovations,
Reflection

Definition of „Self“
Desires
Pending projects

Planning, Negotiation
Thinking about SUE and best response
Learning approach of the generic one-day transport model

\[ k(t,r,j)_{i,n} \]

- Competition for slots on networks and in facilities
- Mental map
- Activity scheduling

\[ q_i \equiv (t,r,j)_{i,n} \]
Equilibrium search in „ABM“ & assignment combinations

Initial schedules

OD aggregation

Assignment

Distribution of schedules

$Q_{ij,t}$

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

$k(t,r,j)_Q$
Equilibrium search in MATSim

Initial schedules

Simulation of flows on networks and to facilities

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

Score (utility) calculation

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

(Optimal) Replanning (inc. connection)

$U_i(t,r,j)_{i,n}$
MATSim today
Following the agents
Initial plan of agent 1:
- Home  8:00
- Leg  0.20  Car  Link 1, 2
- Work  8:00
- Leg  0:20  Car  Link 2,1
- Home  7:40

Agent 2
- Home  8:00
- Leg  0.20  Car  Link 3, 2
- Work  8:00
- Leg  0:20  Car  Link 2, 3
- Home  7:40
List of scheduled events at 8:00

Agent 1  Enter link 1  8:00

Calculate free flow time on link 1  \( dt = 0.15 \)

Agent 2  Enter link 3  8:00

Calculate free flow time on link 3  \( dt = 0.16 \)
List of scheduled events at 8:01

Agent 1  Join queue at end of link 1  8:15
Agent 2  Join queue at end of link 3  8:16
MATSim: Logic of the event-based simulation – Step 4

List of scheduled events at 8:15

Agent 1    Check queue at end of link 1    8:15

Can agent 1 leave the link?
If yes, add
    Agent 1 Leaves link 1    8:15
If no, add
    Agent 1 At end of queue    8:16

Agent 2    Join queue at end of link 3    8:16
MATSim: A GNU public licence software project

Main partners

• TU Berlin (Prof. Nagel)
• ETH Zürich
• senezon (Dr. Balmer, Dr. Rieser)

Coordination via:

• User meeting
• Design meeting
• Developer meeting

• Code committee
• Regular releases of the code
## Known implementations

<table>
<thead>
<tr>
<th>Location</th>
<th>Scale (agents)</th>
<th>Schedules</th>
<th>DTA</th>
<th>Equilibrium</th>
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</tbody>
</table>
Activity scheduling with Vickrey-style utility function

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

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

\[ U_{\text{act},i} = U_{\text{dur},i} + U_{\text{late.ar},i} \]
2010 MATSim: Initial demand

Population: Census-based (sample); Through traffic from surveys

Number, type, sequence and duration of activities:
- Conditional random draw from observed categorised MZ 2000-2005 distributions by person type
- Location of work/school activity:
  - Census commuter matrix
- Location of secondary activities:
  - Random constrained selection or
  - Capacity-constrained MNL within a time-space prism
- Mode choice:
  - MZ-based subtour MNL
- Route choice:
  - Improved A* shortest path
Mode choice: Tour (journey)
Mode choice: Subtour

Subtour 1

Subtour 2

Subtour 3
2010 MATSim configuration: Iteration

Number and type of activities
Sequence of activities

- Start and duration of activity
  - Random mutation
  - Planomat: GA optimiser
- Composition of the group undertaking the activity
- Expenditure division
- Location of the activity

- Location of access and egress from the mean of transport
  - Parking type
- Vehicle/means of transport
- Route/service
- Group travelling together
- Expenditure division
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 computing time breakdown for different iterations and processes.](image-url)
Quality of the results: Overall counts
Quality of the results: A1 at Winterthur (no transit traffic)
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)
• Expenditure division
• Location of the activity (Horni)

• Movement between sequential locations

• Location of access and egress from the mean of transport (Waraich)
  • Parking search and type (Ciari)
• Vehicle/means of transport (Ciari)
• Route/service
• Group travelling together (Dubernet)
• Expenditure division
Adding induced demand
Joh’s 2004 utility function for activities

\[ U_{perf,ij}(t_{perf,ij}) = U_{ij}^{min} + \frac{U_{ij}^{max} - U_{ij}^{min}}{(1 + \gamma_{ij} \cdot \exp[\beta_{ij}(\alpha_{ij} - t_{perf,ij})])^{1/\gamma_{ij}}} \]

Diagram showing the relationship between \( U_{perf,ij} \) and activity duration.
Planomat-X with schedule recycling

Utility in utility point

Travel distance in meters

Travel time in seconds

MATSim iteration

0 5 10 15 20 25 30 35 40 45 50

Utility curves showing the trend of utility points over MATSim iterations.

Travel distance and travel time curves showing the trend over MATSim iterations.
Planomat-X with schedule recycling

Initial score = 2.28

Final average utility score of executed schedules (in utility points)

Replanning runtime* per agent (in msec)

Initial score = 2.28

* 15

151

676
New tools

Video available at http://vimeo.com/30826962
Nodes map-to-map-matching tool

Video available at http://vimeo.com/30826962
Interactive capacity and free speed fixing tool

Video available at http://vimeo.com/30826962
Results: Capacity changes

- 3550 veh/hr

+ 8000 veh/hr
Bus routes map matching problem
Algorithm

For each pair of consecutive stops in a route:
1. Selection of candidate links related to the departure stop
2. Selection of candidate links related to the arrival stop
3. Shortest path algorithm between each pair of links
4. Selection of the best path

Save selected links and path, continue with the next pair of stops

Video available at http://vimeo.com/30826962
Demonstration

Video available at [http://vimeo.com/30826962](http://vimeo.com/30826962)
Interaction between car and buses (purple)

Without buslane:
Adam Rd / PIE

With buslane:
Gelyang Rd, aft Sims Way

Source: maps.google.com
Simulation of public transport supply in Singapore

Video available at http://vimeo.com/37719740
Wider challenges for transport modelling
Social networks, e.g. Current snowball sample

Anzahl per 4km²

- 1 - 8
- 9 - 28
- 29 - 68
- 69 - 169
- 170 - 323

- Landesgrenze
- Sprachgrenze
Social networks, e.g. Linked ego-centric networks
Longer term projects

Mean = 1.63
Std. Dev. = 1.69
N = 718

Number of larger projects in the last 5 years
Integration of land use (optimisation)

ΔPopulation
Δgrowth
ΔPrices
ΔClimat

ΔPopulation
Δgrowth
ΔPrices
ΔClimat

Travel and land use model

Impacts and Mass flows

Space/mass optimisation

GIS³

Grammars landscape
Grammars urban design
Grammars infrastructure
Regulation/laws
Sustainability
Network optimisation
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
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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
Dr. David Stripppgen
Michael Van Eggermond
Rashid Waraich
Michael Zilske
Questions?

www.matsim.org
www.ivt.ethz.ch
www.futurecities.ethz.ch
www.senozon.ch