Michael Balmer, balmer@ivt.baug.ethz.ch

Integrated Activity-Based Demand Modeling and Traffic Assignment on Micro-Level for Very Large Scenarios

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

MATSim
Multi-Agent Transport Simulation

Outline

- *Motivation: Past and Present*
- *Introduction: Multi-Agent Transport Simulation (MATSim)*
- *Application: Switzerland in Detail*
- *Results: Switzerland in Numbers*
- *Discussion: Strength and Weakness*
- *Outlook: Into Specialization*

Motivation:
Past and Present

Questions in the past

CH Motorway projects in the ’70…’90:

- Daily volumes
- Peak hour volumes
- Reachability
- Travel time
- Modal-split
- ...

Questions today (1)

Time dependent road pricing in Zurich

- Who pays? How much? When?
- Who tries to avoid costs? When? Where?
- Who switches to public transport?
- Which regions benefit by that? In relation to others? Social? Economical? Ecological?
- Which shops/companies benefit by that? When?
- Socio-economic an -ecologic value? Per region?
- ...

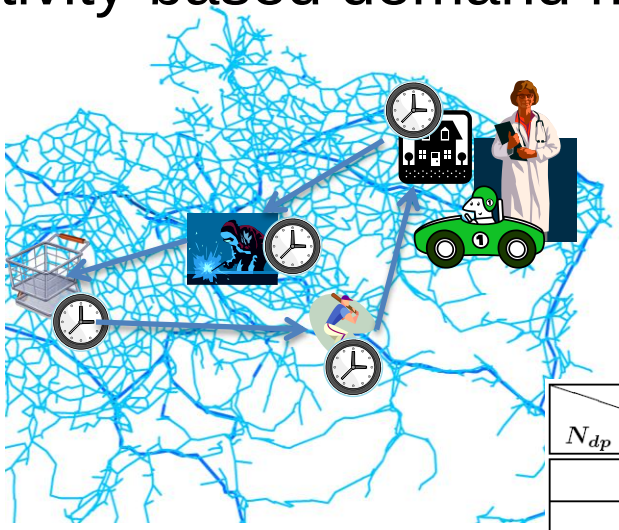
Questions today (2)

30% electric vehicles:

- What is the size of the time dependent system load of a *speed charging* fuel station?
- When do peaks of the system load occur?
- What incentives has to be given to the cusomers such that the demand peaks will be distributed over the day?
- To whom should the incentives be provided?
- ...

ABD & DTA

activity-based demand modeling



matrices

N_{dp} \ N_{ar}	A: 0	B: 3	C: 1	D: 2	E: 3
A: 6	0	1	0	2	3
B: 0	0	0	0	0	0
C: 0	0	0	0	0	0
D: 0	0	0	0	0	0
E: 3	0	2	1	0	0

dynamic traffic assignment

flows

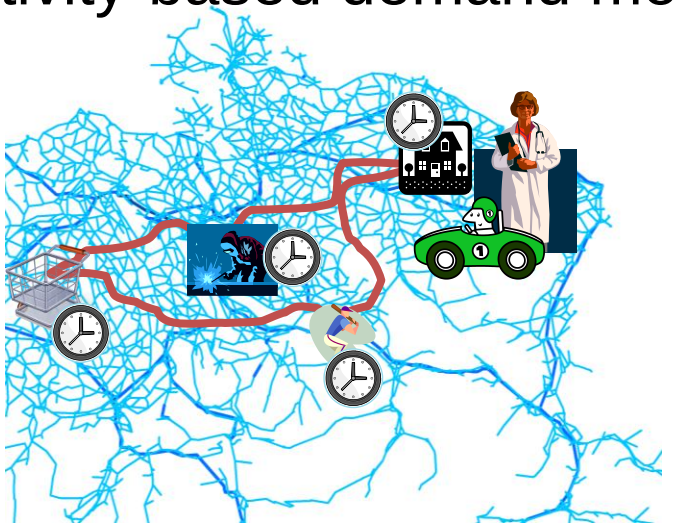
costs

MATSim
Multi-Agent Transport Simulation

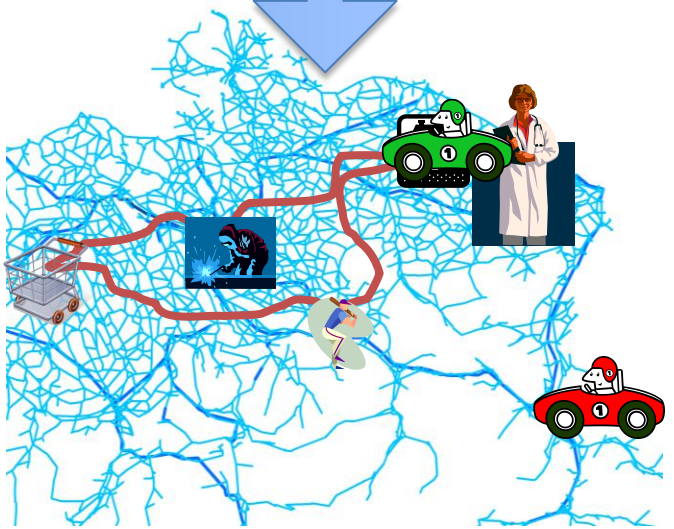
Who? When? Where?

ABD & DTA *integrated*

activity-based demand modeling (incl. routes)



individual, time dependent, daily demand („schedule“, „plan“)



individual, dynamic, microscopic shares of costs

physical simulation

MATSim
Multi-Agent Transport Simulation

Introduction:
Multi-Agent Transport Simulation
(MATSim)

MATSim (1)

Dynamic, individual, microscopic demand model

[[[OTF: pdf slide show]]]

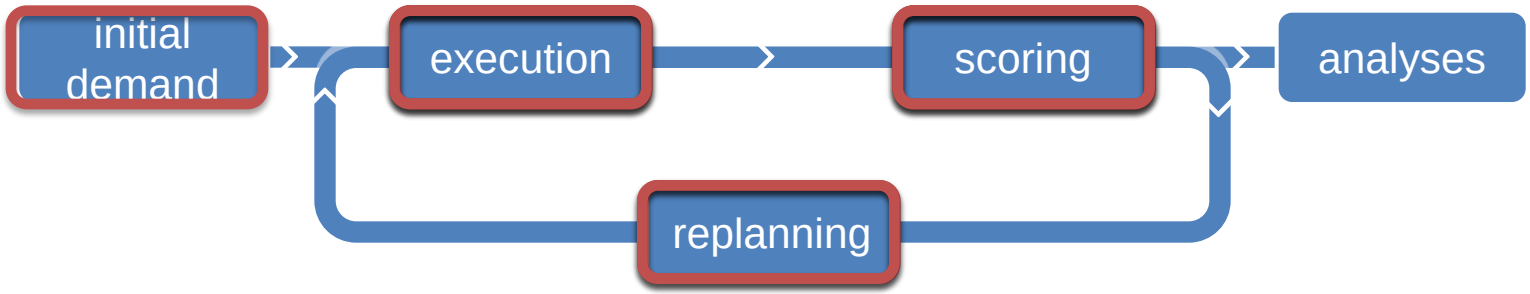
MATSim
Multi-Agent Transport Simulation

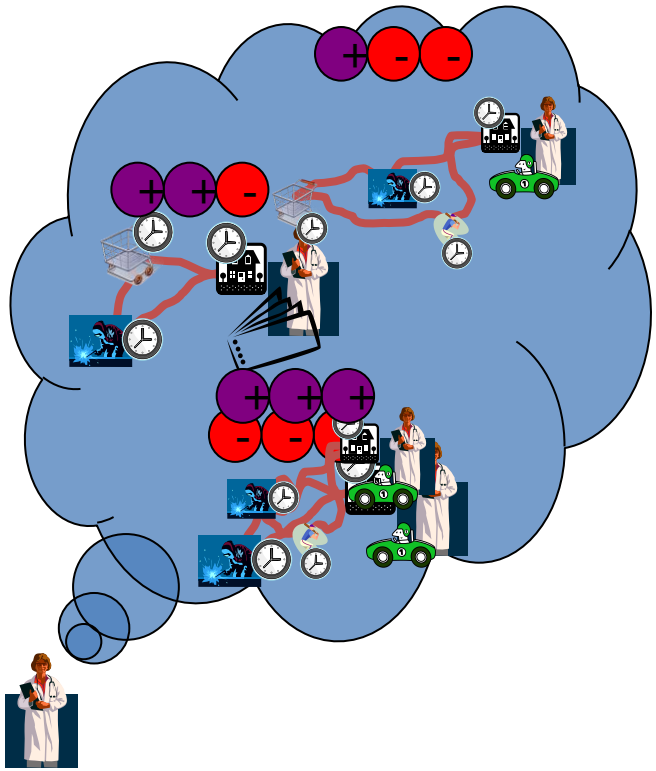
MATSim (2)

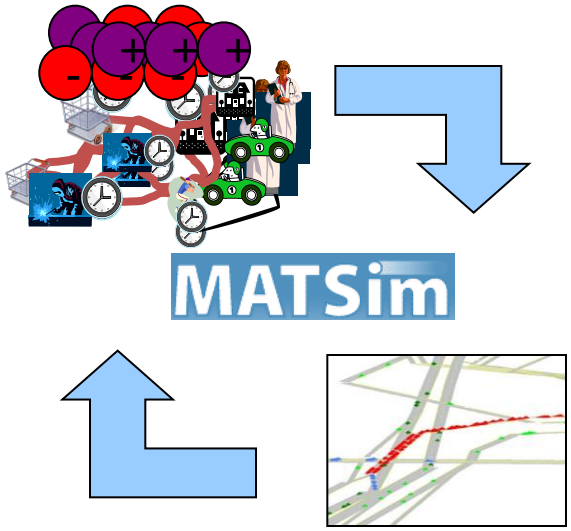
Level of details of information per individual

(Source: Rieser, 2008, MATSim Seminar, Castasegna)

MATSim (3)







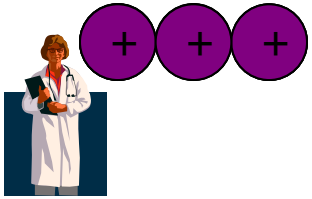
+sports
- congestions
- closed shop

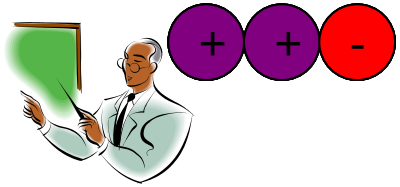
MATSim
Multi-Agent Transport Simulation

MATSim (4)

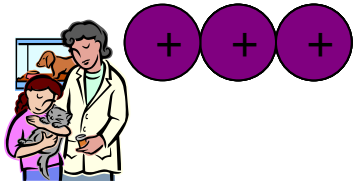
Relaxation (NE)

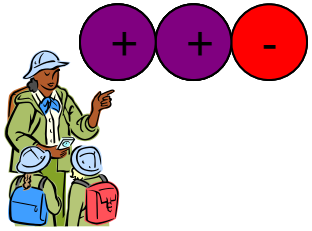
Iteration n





etc.



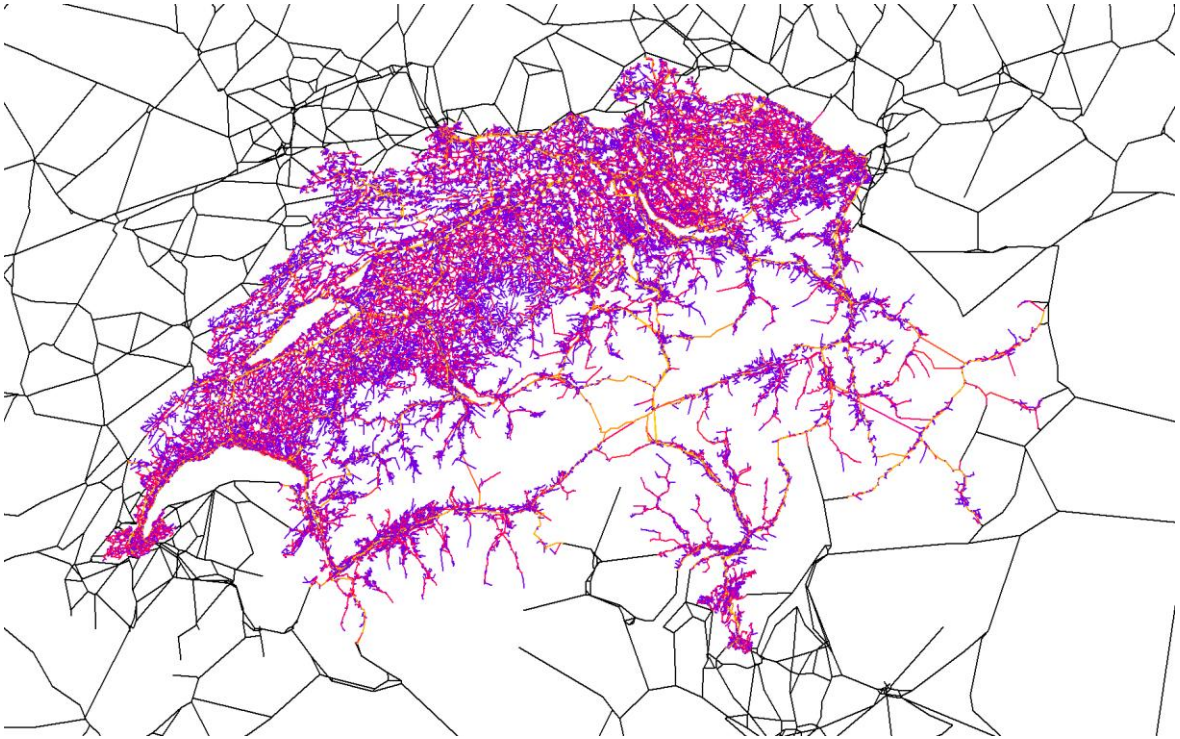


➔ **stable state**

Application:
Switzerland in Detail

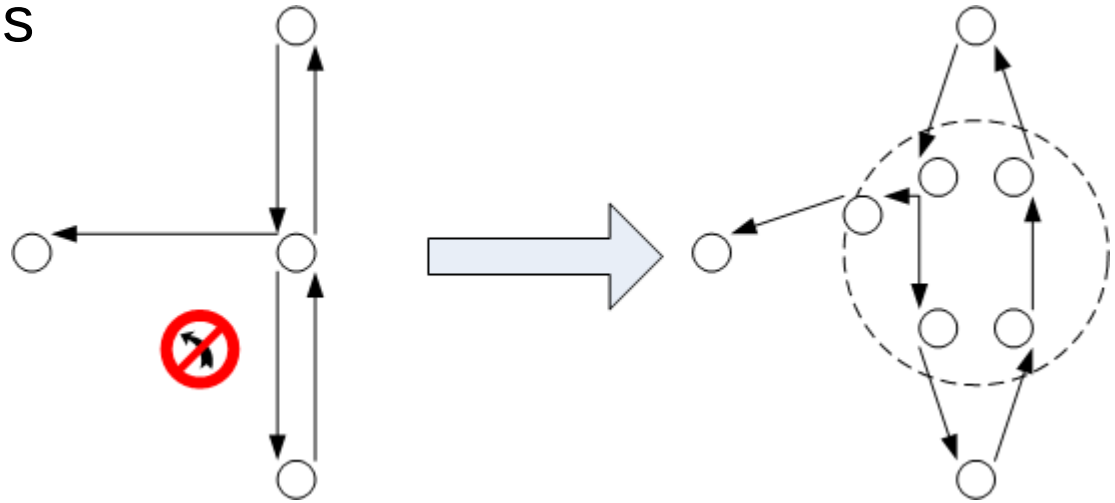
Data: Network

- High resolution navigation network (Tele Atlas) including a "turn restrictions" model



Data: Network (2)

turn restrictions



➔ network with 1.3 Mio links

network optimization

➔ network with 1 Mio links

Data: Activities & Facilities

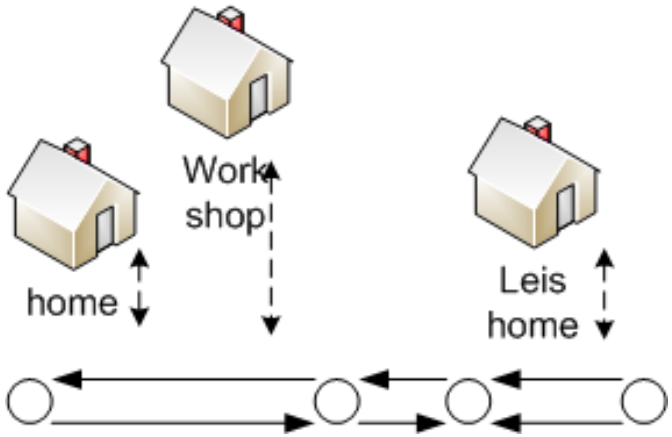
Facilities & activity opportunities:

➔~1.61 Mio facilities

➔~1.72 Mio activity opportunities

➔11 different activity types

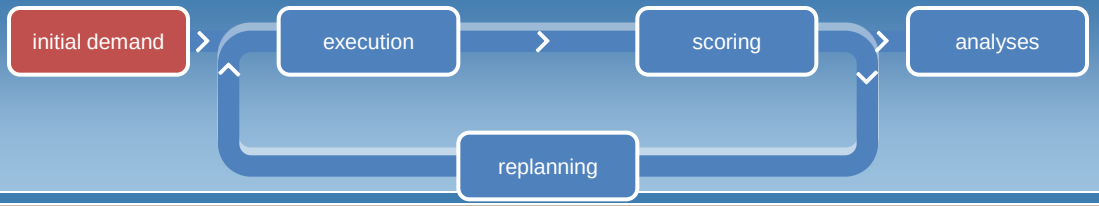
➔Storage capacities, opening times



➔ ~950‘000 „zones“

Data sources: Datapuls building data 2008 & Federal Enterprise Census 2001 (Meister, 2008)

Data: IIDM



Individuals:

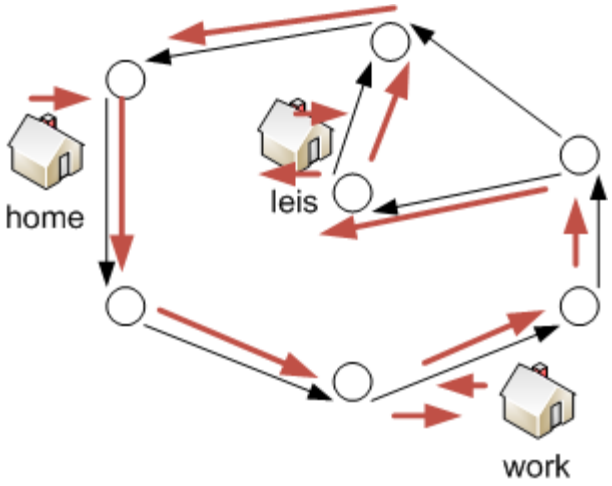
- ➔Id, attributes (e.g. age, driving license, pt time tickets, etc.)
- ➔Primary activity location („home“, „work“, „education“)
- ➔Personal preferences (desired activity duration)

Demand:

- ➔Dynamic, individual, activity based, micro-demand for all inhabitants of Switzerland

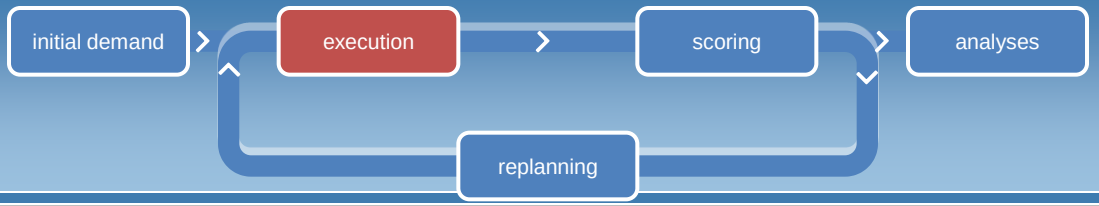
Data sources: Micro census 2005, census 2000, Datapuls person dataset

(Balmer *et al*, 2008, 2009; Ciari *et al*, 2008)



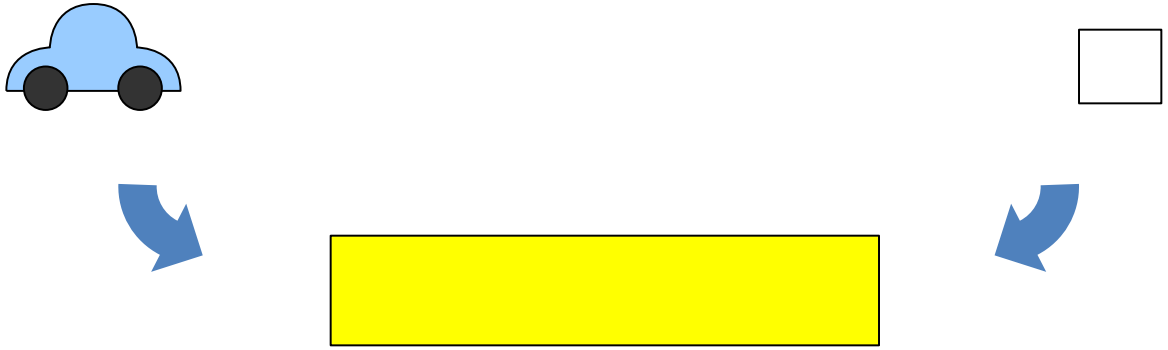
MATSim
Multi-Agent Transport Simulation

Simulation



Queueing model with more realism:

➔„returning gaps“ (Charypar, 2007)

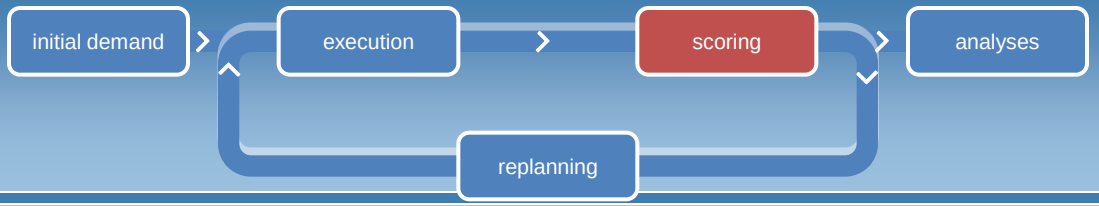


➔Event driven instead of time steps (Charypar, 2006-2008)

➔Parallel event processing (Waraich, 2009)

MATSim
Multi-Agent Transport Simulation

Utility (1)



Extension of the Charypar und Nagel (2006) utility function based on the Vickery model:

$$U_{plan} = \sum_{i=1}^{n} (U_{act,i} + U_{travel,i})$$

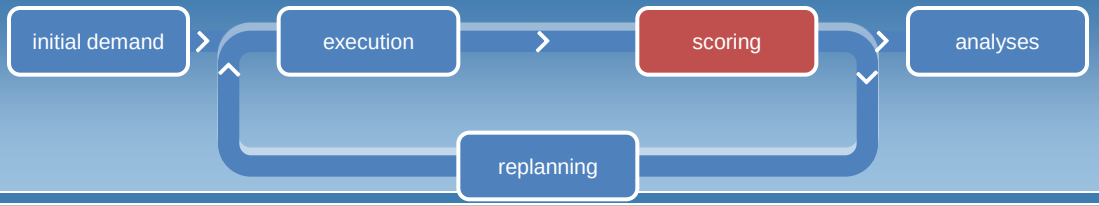
➔ Activities:

$$U_{act,i} = (U_{cum,j} - U_{cum,j-1}) \cdot f_p + U_{wait,i} + U_{short,i}$$

$$U_{cum,j} = \begin{cases} max\left(0, \beta_{perf} \cdot t^* \cdot ln\left(\frac{\sum_{k=1}^{j} t_{perf,k}}{t_0}\right)\right) & j > 0 \\ 0 & j = 0 \end{cases}$$

$$f_p = \begin{cases} min\left(\beta_{load,1} \cdot \left(\frac{load}{capacity}\right)^{\beta_{load,2}}, 0.5\right) & \text{, if activity type } \in \{\text{shop, leisure}\} \\ 1.0 & \text{otherwise} \end{cases}$$

Utility (2)

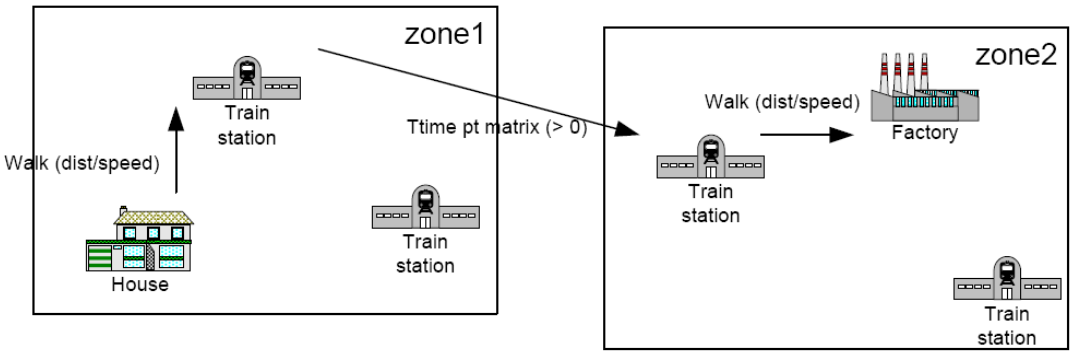


➔ Traveling:

$$
\begin{aligned}
U_{travel,i,car} &= const_{car} + \beta_{tt,car} \cdot t_{car} + \beta_{cost,car} \cdot c_{car} \\
U_{travel,i,pt} &= \beta_{tt,walk} \cdot (t_{access} + t_{egress}) + \beta_{tt,pt} \cdot t_{pt} + \beta_{cost,pt} \cdot c_{pt} \\
U_{travel,i,bike} &= const_{bike} + \beta_{tt,bike} \cdot t_{bike} \\
U_{travel,i,walk} &= \beta_{tt,walk} \cdot t_{walk}
\end{aligned}
$$

➔ Travel times:

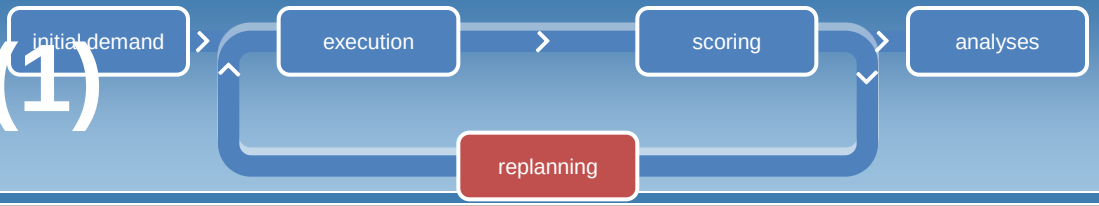
- ➔ MIT: micro simulation (queue model)
- ➔ Walk&Bike: crow fly distance with fixed speed
- ➔ PT:



➔ The MATSim micro simulation is a hybrid model at the moment!

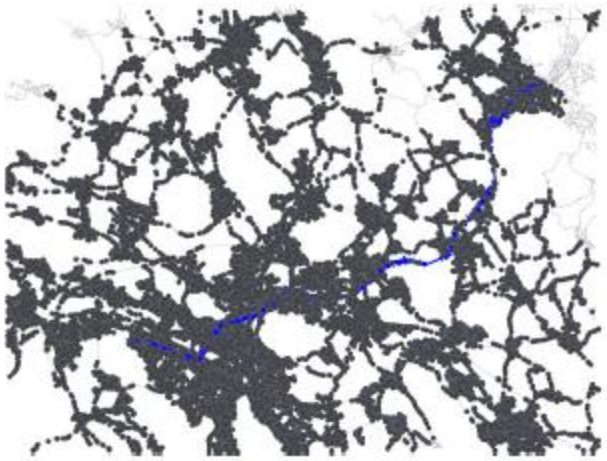
MATSim
Multi-Agent Transport Simulation

Search space (1)

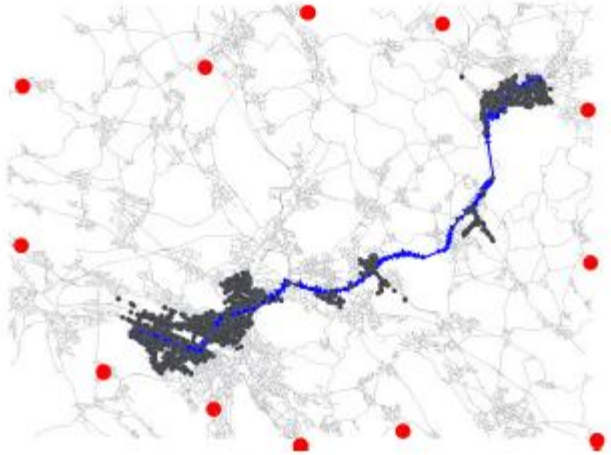


Router module:

➔ Dynamic least-cost router at geo networks (Landmarks-A* Router, Lefebvre, 2007)



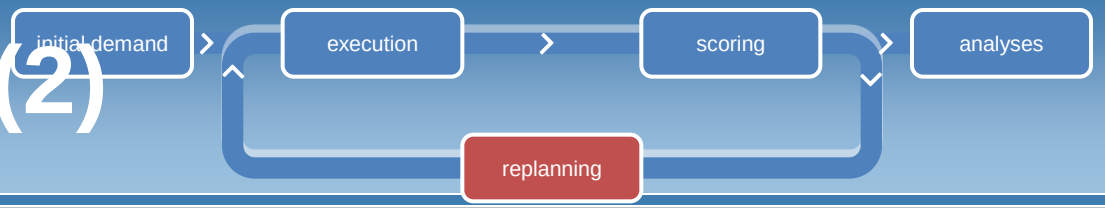
Basic/Iteration-ID Dijkstra



Landmarks A* (using 12 landmarks)

MATSim
Multi-Agent Transport Simulation

Search space (2)

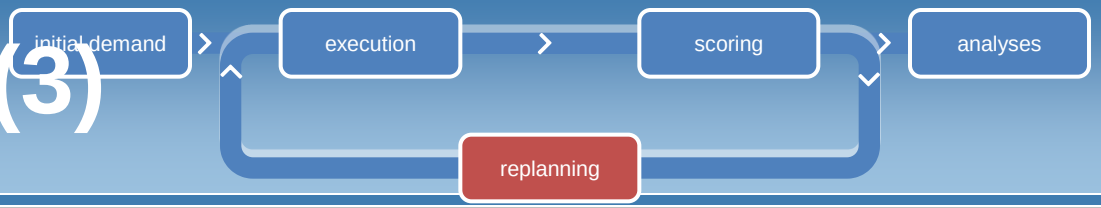


"Planomat" module:

➔ Multi-space optimization of an individual's schedule
Here: Departure time choice, activity duration choice and mode choice at sub-tour level of detail (Meister, 2010)

MATSim
Multi-Agent Transport Simulation

Search space (3)



Secondary location choice module:

Choice set generation via:

➔Selection of secondary activity locations via space-time-prisms based on estimated time budgets (arrival, departure and activity duration), or

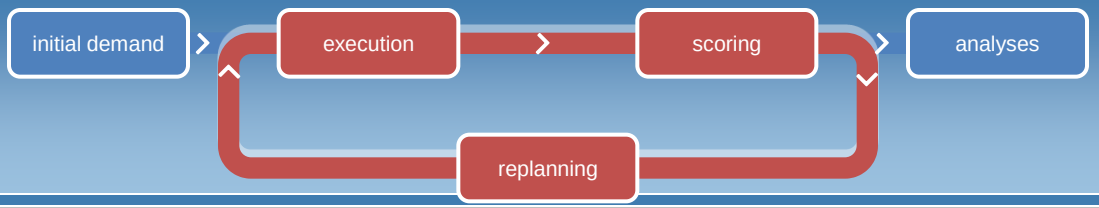
➔Universal choice set

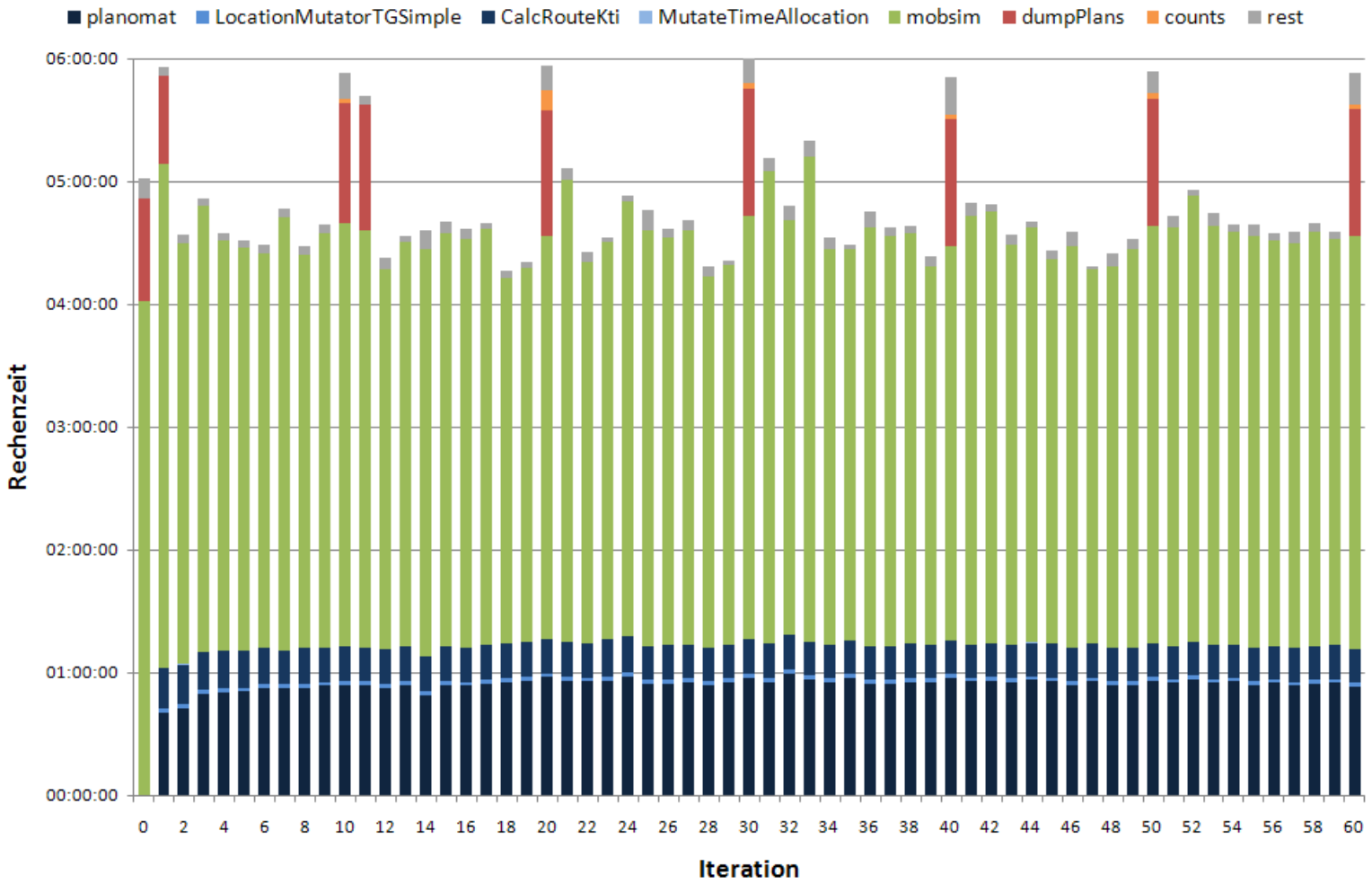
Capacity restraint function

➔Attraction measures via facility load (time dynamic)

(Horni, 2009)

Performance





MATSim
Multi-Agent Transport Simulation

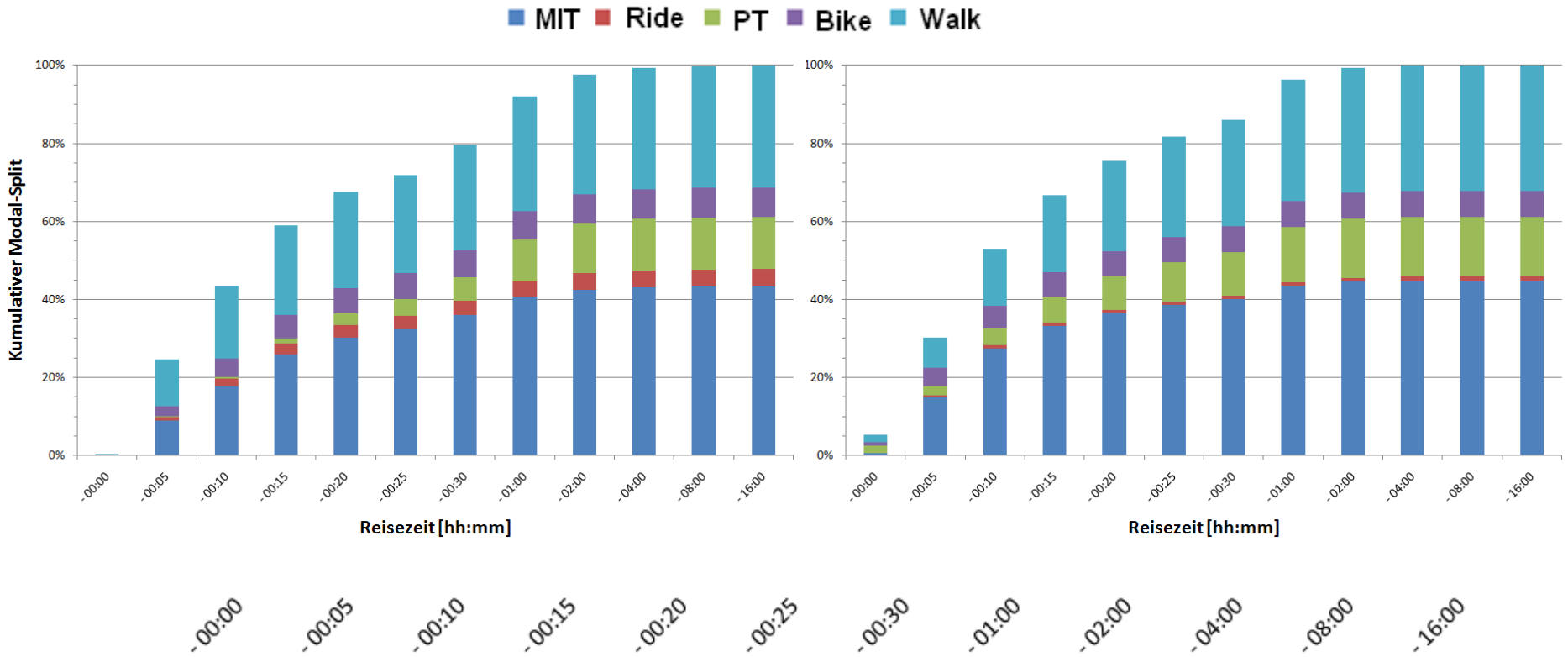
Results:
Switzerland in Numbers

Mode share

travel mode	microcensus	MATSim
car	43.3%	44.9%
share a ride	4.4%	0.9%
public transit	13.4%	15.3%
bike	7.6%	6.6%
walk	31.3%	32.2%

Travel time distribution per mode

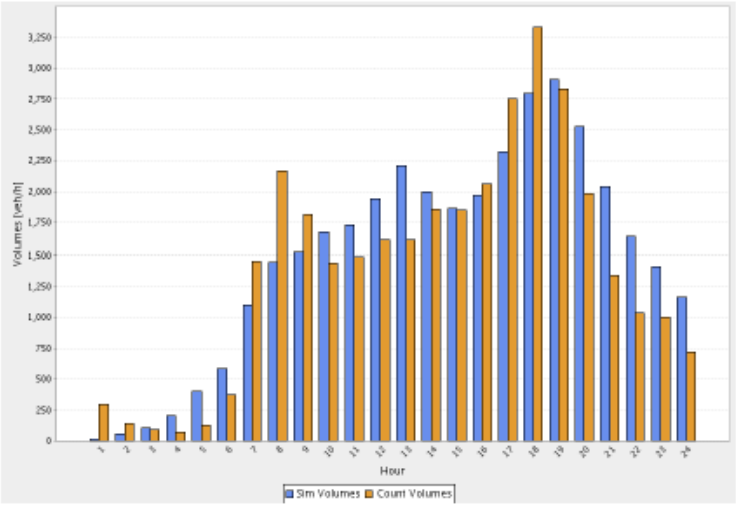
Microcensus 2005 vs. MATSim



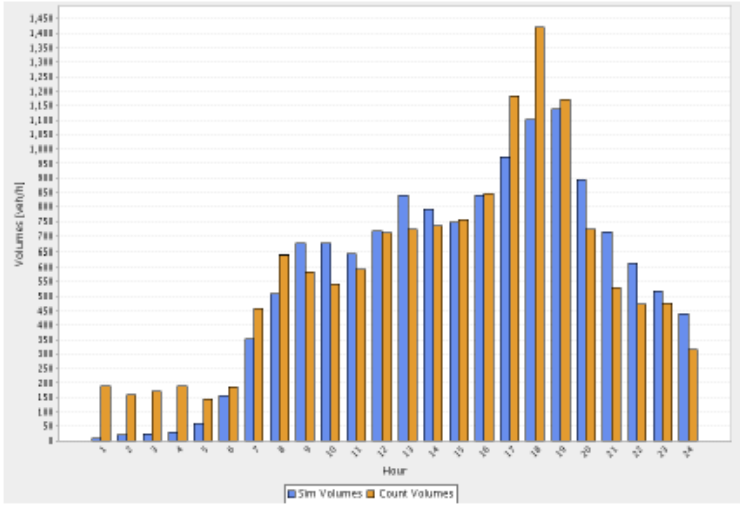
MATSim
Multi-Agent Transport Simulation

Traffic counts

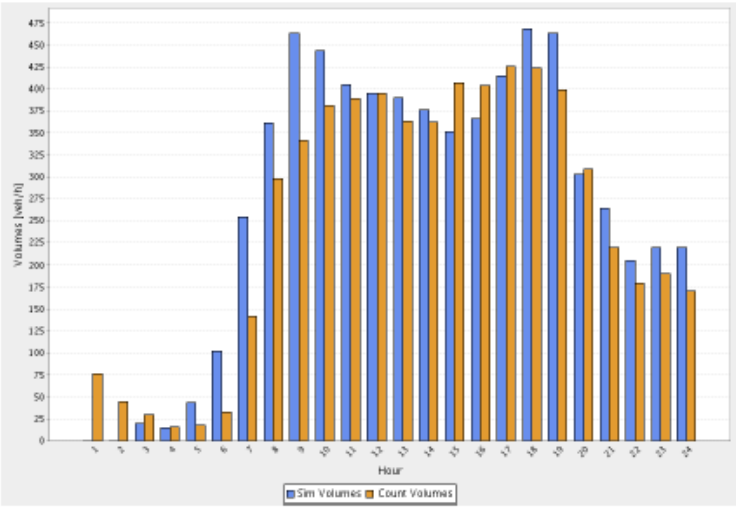
(a) Pendlerstecke: Autobahn A53 von Brüttisellen nach Uster



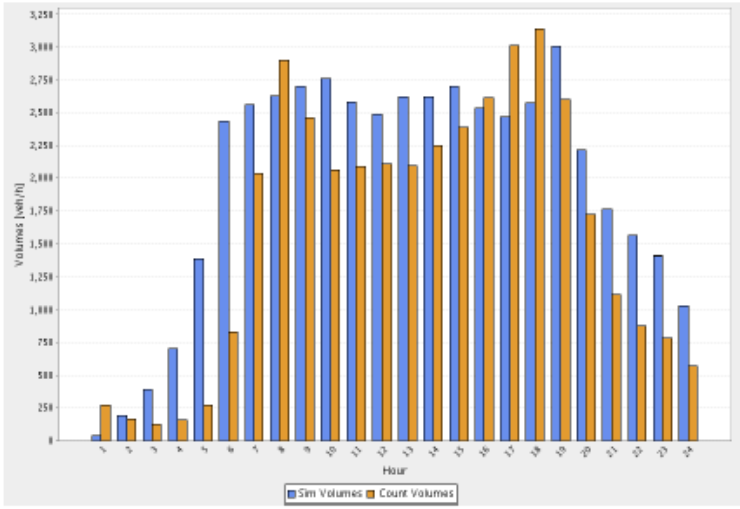
(b) Zubringerstrecke: Wehntalerstrasse von Affoltern nach Regensdorf



(c) Innenstadt: Talstrasse Richtung Nord-West

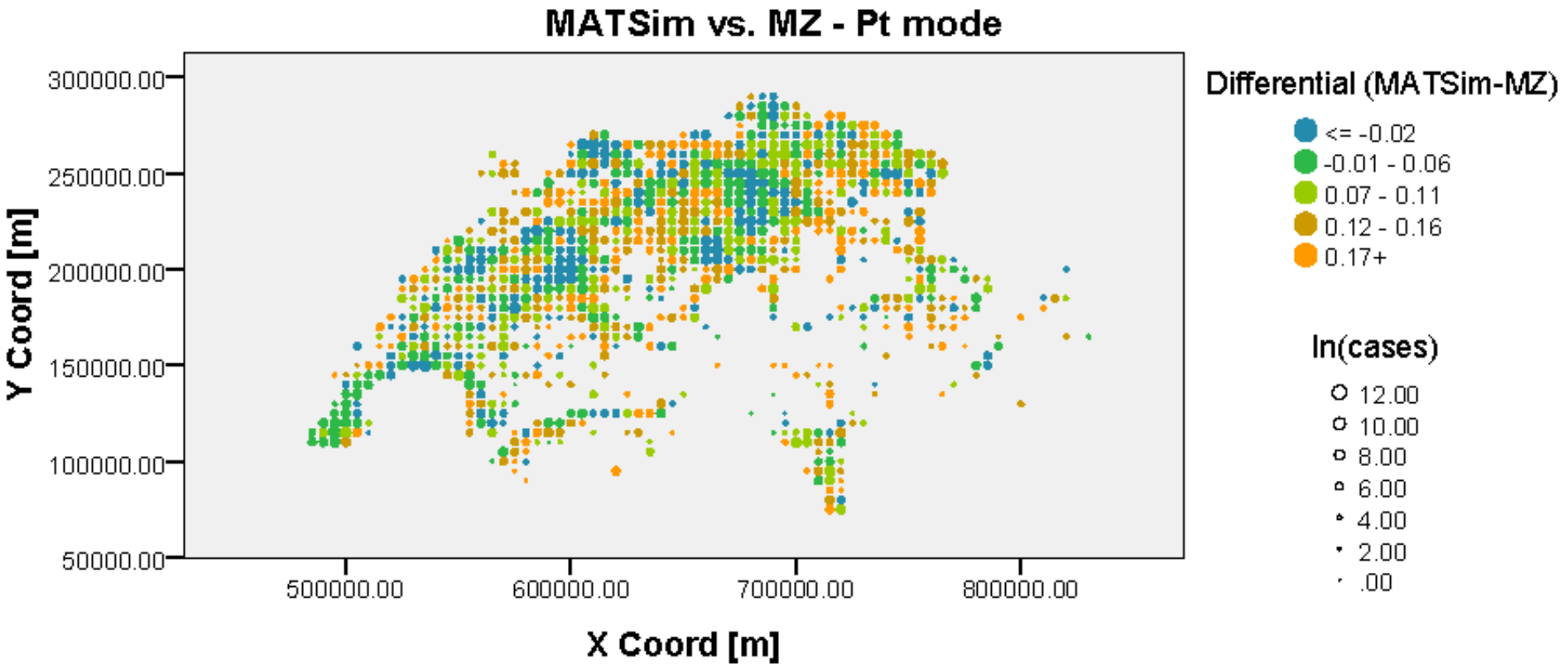


(d) Hauptachsen: Autobahn A1 bei Härkingen Richtung Bern



TSim
Transport Simulation

Mode share: Spatial distribution PT



MATSim
Multi-Agent Transport Simulation

Discussion:

Strength und Weakness

Discussion (1)

+ True integration of ABD & DTA
+ Quality of the outcome similar to macro models
+ Access to detailed (socio-)demography during the whole process ➔ high resolution (links, facilities), time dynamic, individual mobility information
+ Size & speed
+ Feedback
+ Flexibility for pre- and post-process analysis
+ Modular, flexible, extensible
+ Open source

Discussion (2)

-/+ Need of more detailed input data

-/+ Calibration

- Sensitive reactions to errors in the input data
- “Out of the box” analysis
- Mathematical prove still open
- “simple” models that are “difficult” to explain

Outlook:
Into Specialization

Projects

- *Sustain City*: Integration of MATSim and UrbanSim
- *EWZ*: Estimation of future energy need
- *Evacuation*: NE versus system optimum
- *BVG*: Client based modeling of future public transport need
- *Car sharing*: Location optimization
- *Network evolution*: Synthetic design vs. urban growth of transport networks
- *Replanning complete plans*: Feil (2010)
- *Multimodal micro simulation*: Rieser (2010)

(See www.ivt.ethz.ch)

Finally…

Agent-based simulation for transport planning is not yet *convenience food*: One has to go to the fields to seed the vegetables, but after a lot of work the harvest will be rich.

The transport planners concentrate on the choice of vegetables but the computer centers should do the gardening. At the end, we get a rich and tasty menu for the stakeholders."

http://matsim.org

http://www.ivt.ethz.ch/vpl/publications/reports/ab613.pdf

Meister, K., M. Balmer, F. Ciari, A. Horni, M. Rieser, R. A.Waraich and K.W. Axhausen (2010) Large-scale agent-based travel demand optimization, paper presentation at the 12th World Conference on Transportation Research, Lisbon, July 2010.