Francesco Ciari, ciari@ivt.baug.ethz.ch

MATSim, an agent based traffic simulator

Concepts, framework, and applications

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

MATSim
Multi-Agent Transport Simulation

PART 1:The multi-agent microsimulation toolkit

MATSim at a glance

Agent and activity based simulation of transportation demand (Scheduling) and transportation supply (Network).

- Java-Implemented
- Open source (GNU license)
- Jointly developed at ETH Zurich and TU Berlin
- www.matsim.org

Agent-Based

The actors of the modeled system are represented at individual level and act in an artificial environment, according to given rules, pursuing a given goal and having learning capabilities.

Agent-Based

The actors of the modeled system are represented at individual level and act in an artificial environment, according to given rules, pursuing a given goal and having learning capabilities.

The behavior of the system „emerges“ from the simulation as a consequence of individual agents‘ behavior

Activity-Based

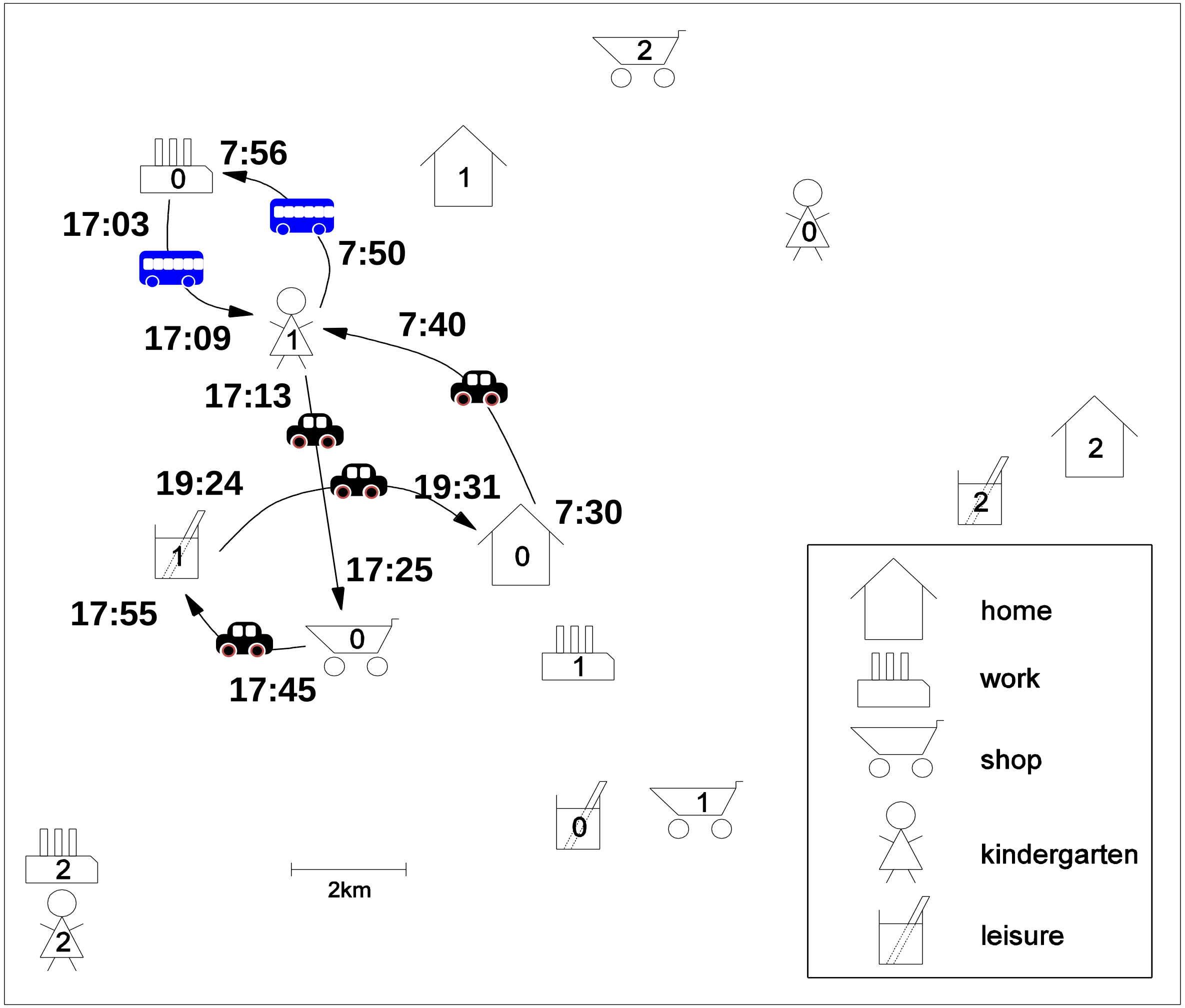
Traffic is the consequence of the need of persons to perform activities at different places.

Activity-Based

Traffic is the consequence of the need of persons to perform activities at different places.

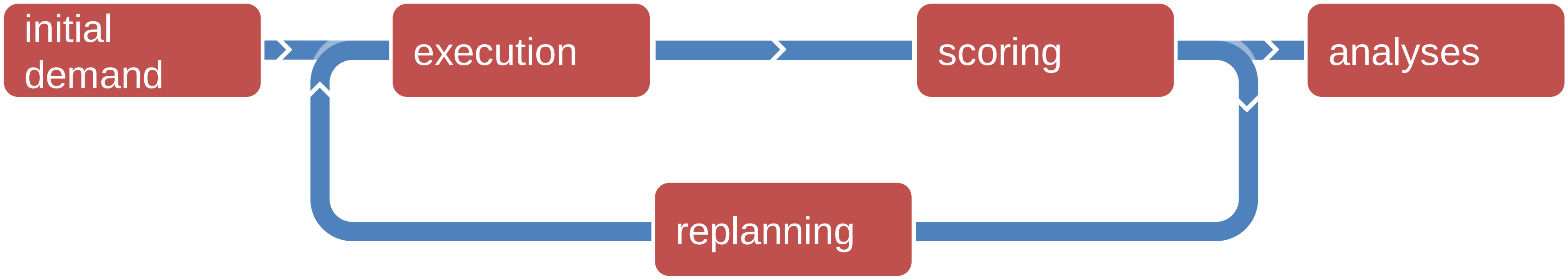
If we can model activities of persons we can obtain the transportation demand as „side-product“ of the simulation

Day-plan

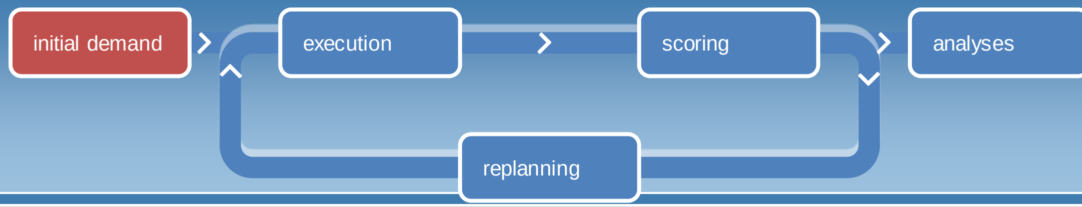


2
7:56
0
1
17:03
7:50
0
17:09
1
7:40
17:13
2
19:24
19:31
2
7:30
1
0
17:25
17:55
0
1
17:45
home
work
shop
kindergarten
0
1
leisure
2
2km
2

MATSim Framework



Demand



Persons:

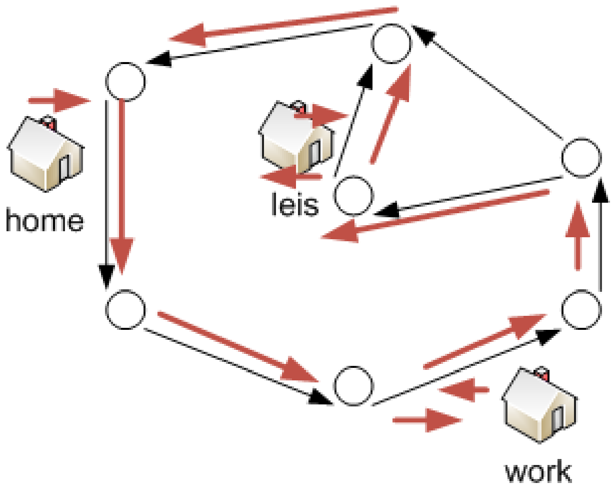
- ➔ Attributes (i.e. Age, Gender, Driving license, Car owneship, etc.)
- ➔ Primary activities („Home“, „Work“, „Education“)

Source: Census, Synthetic Population

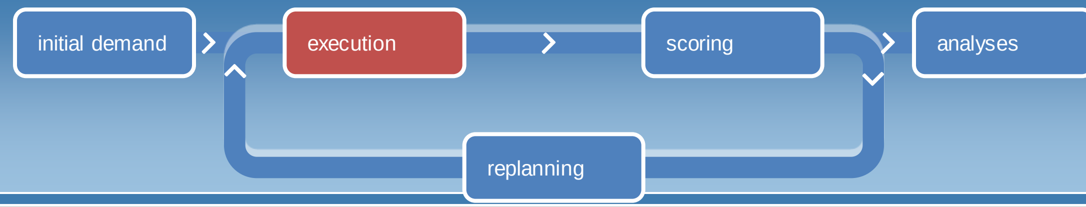
Demand:

- ➔ Initial Day-plans

Source: Travel diaries survey



Execution



- “Physical” Simulation of the day-plan
- Interaction among agents
- Basis for the calculation of the utility (score) of the plan for the person

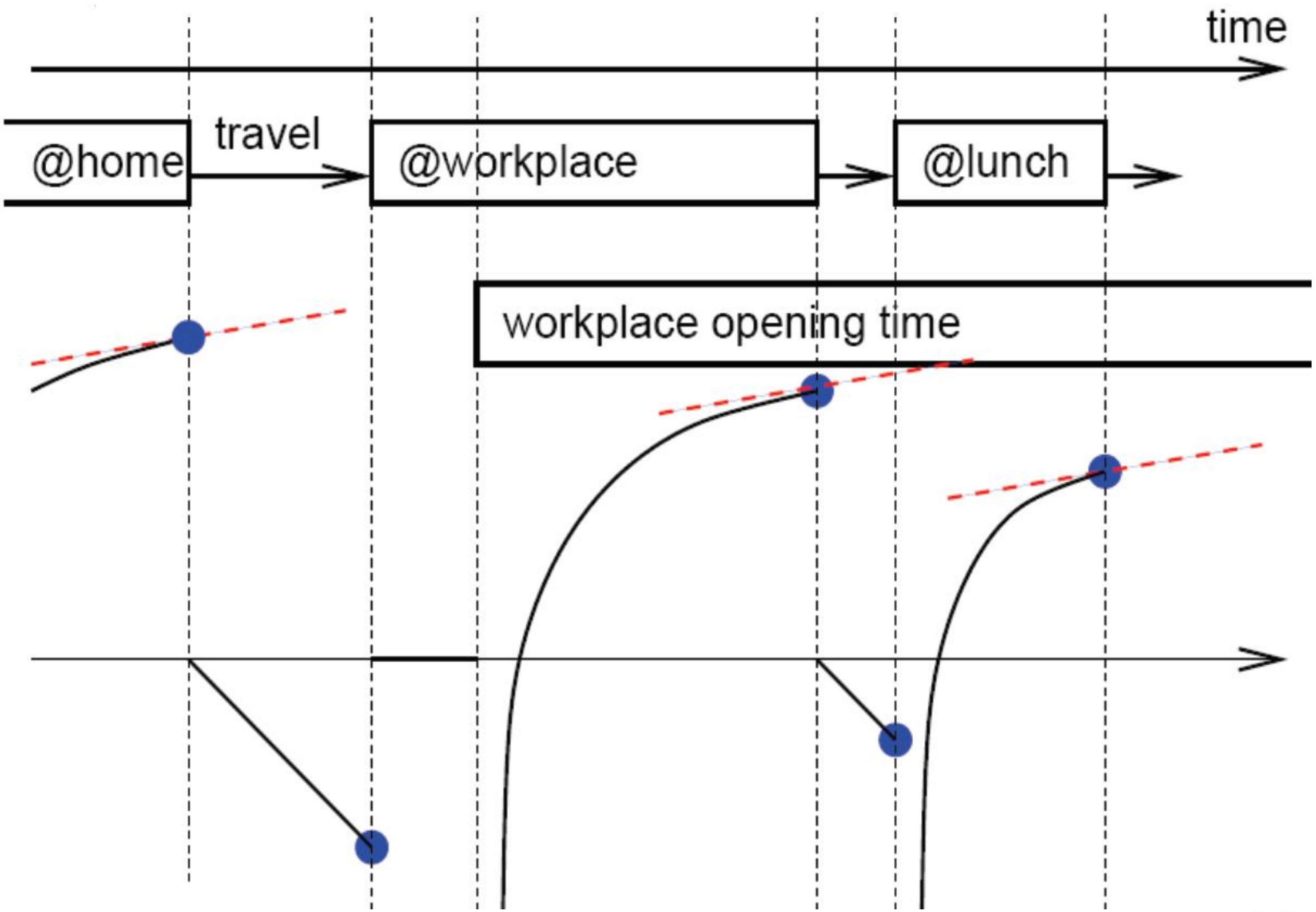
MATSim Utility function:

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

$$U_{travel} = \sum_{j=1}^{n} \alpha_j + \beta^1{}_j * TT + \beta^2{}_j * Cost_j * Dist$$

- Available Activities: Home, Work, Education, Shopping, Leisure
- Available modes: Car, PT, Bicycle, Walk,

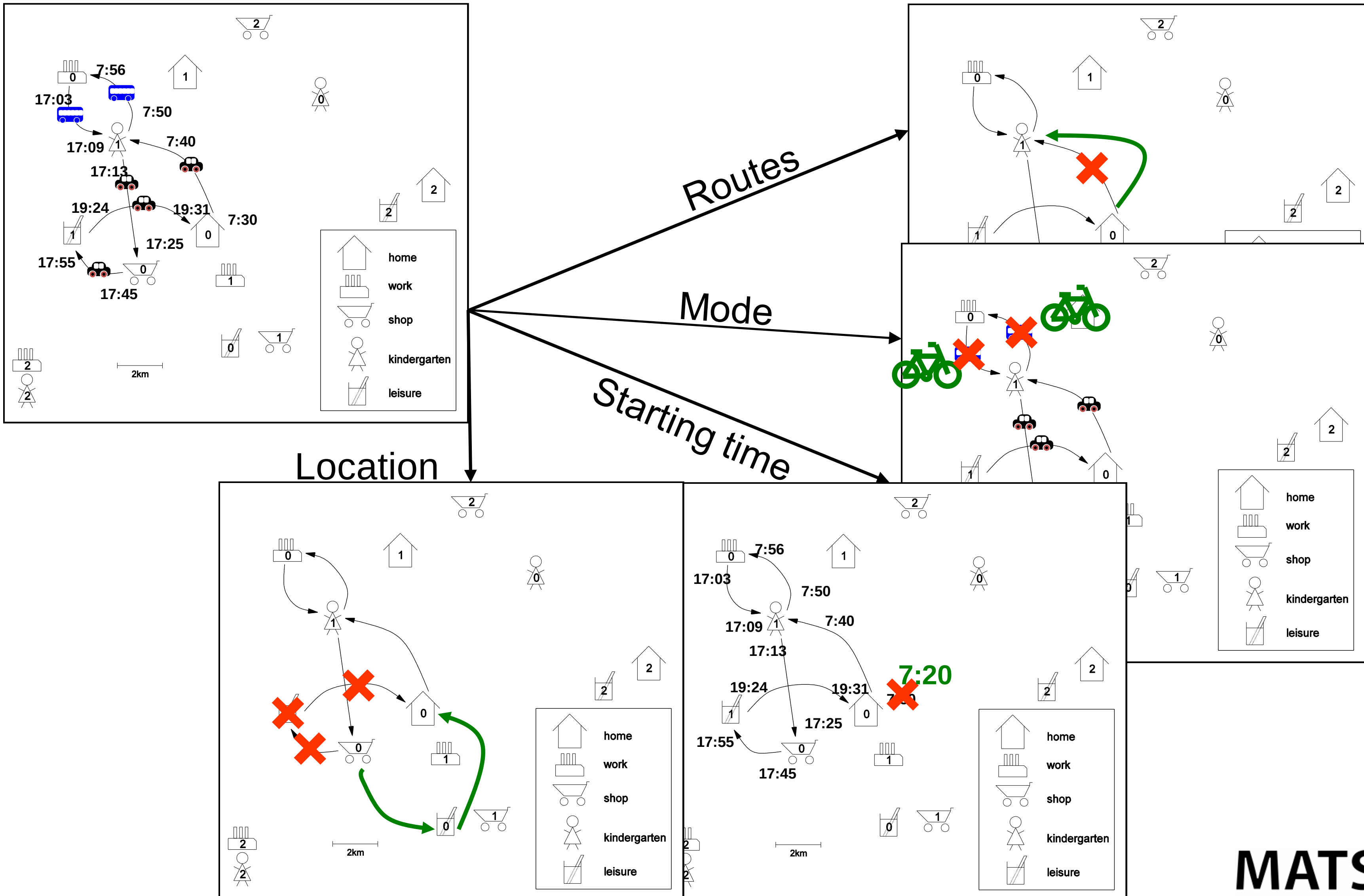
Scoring



Replanning

initial demand → execution → scoring → analyses

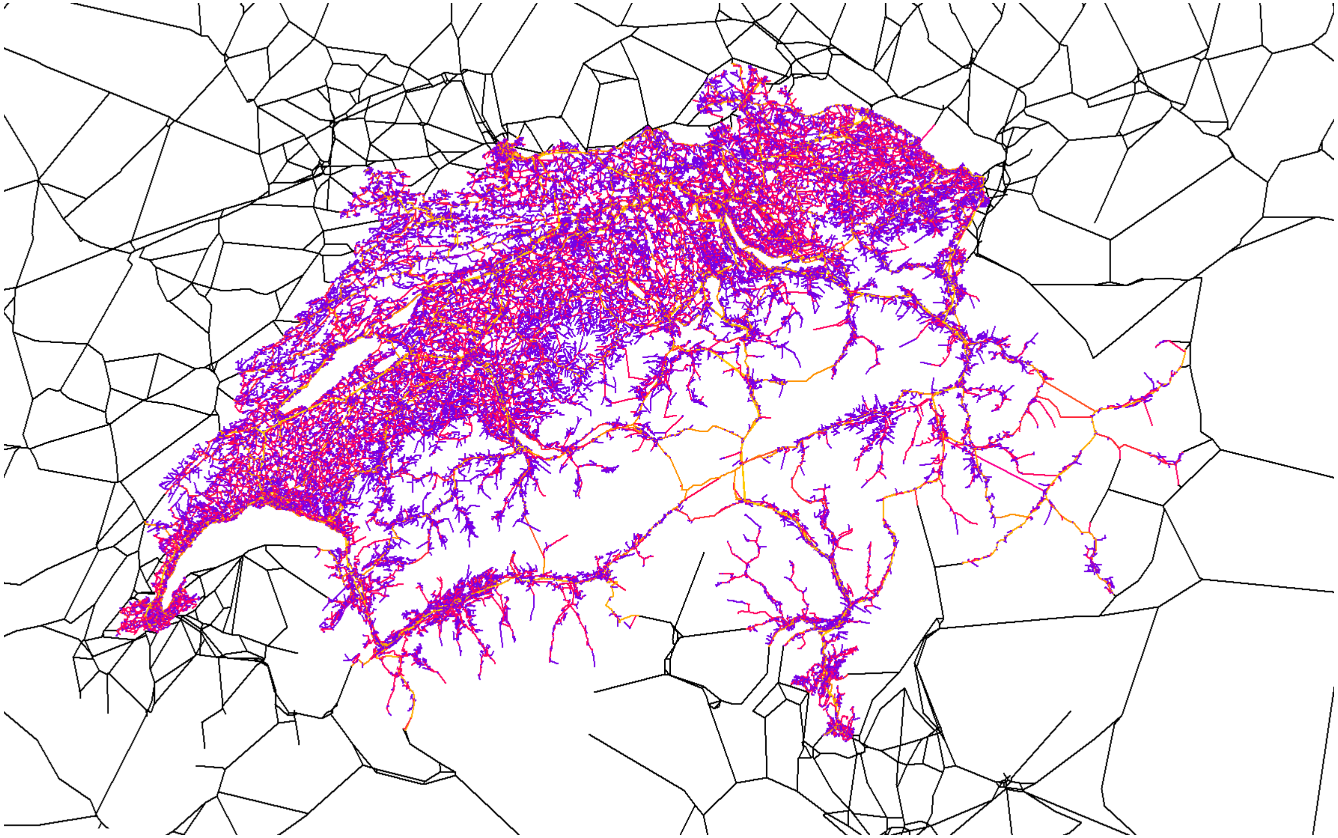
replanning



MATSim
Multi-Agent Transport Simulation

Road network

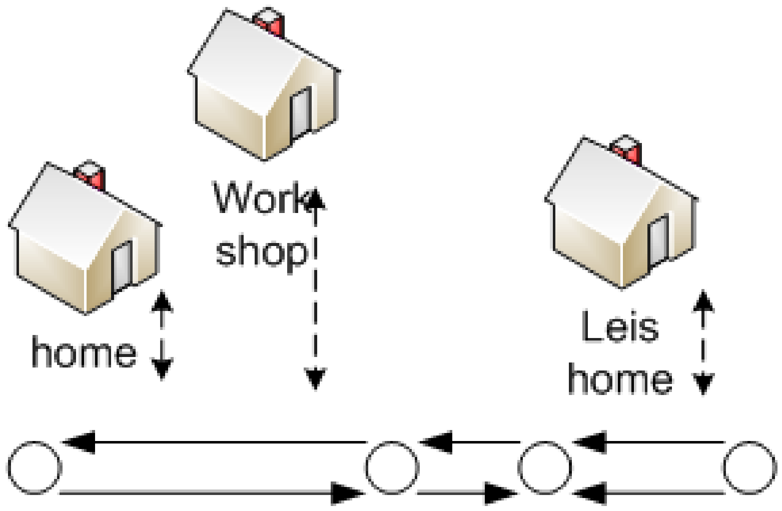
High resolution navigation network, including turning rules



Facilities

„Facilities“:

- Building location
- Activity options
- Capacity, Opening time



Source:

Enterprise register, Building register

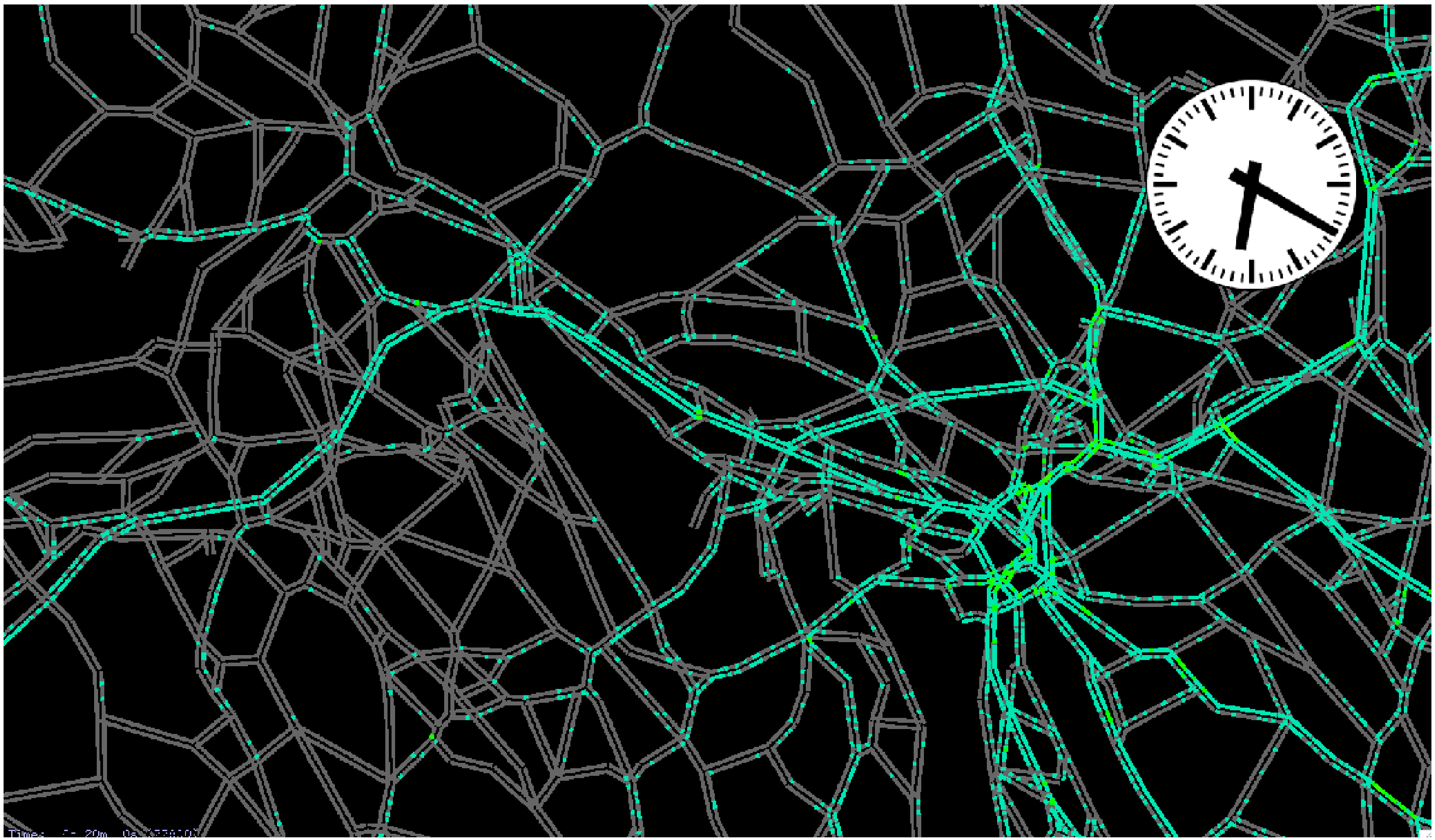
Performance - Scenario

- Transportation system in Switzerland
- 24 h of an average Work-day

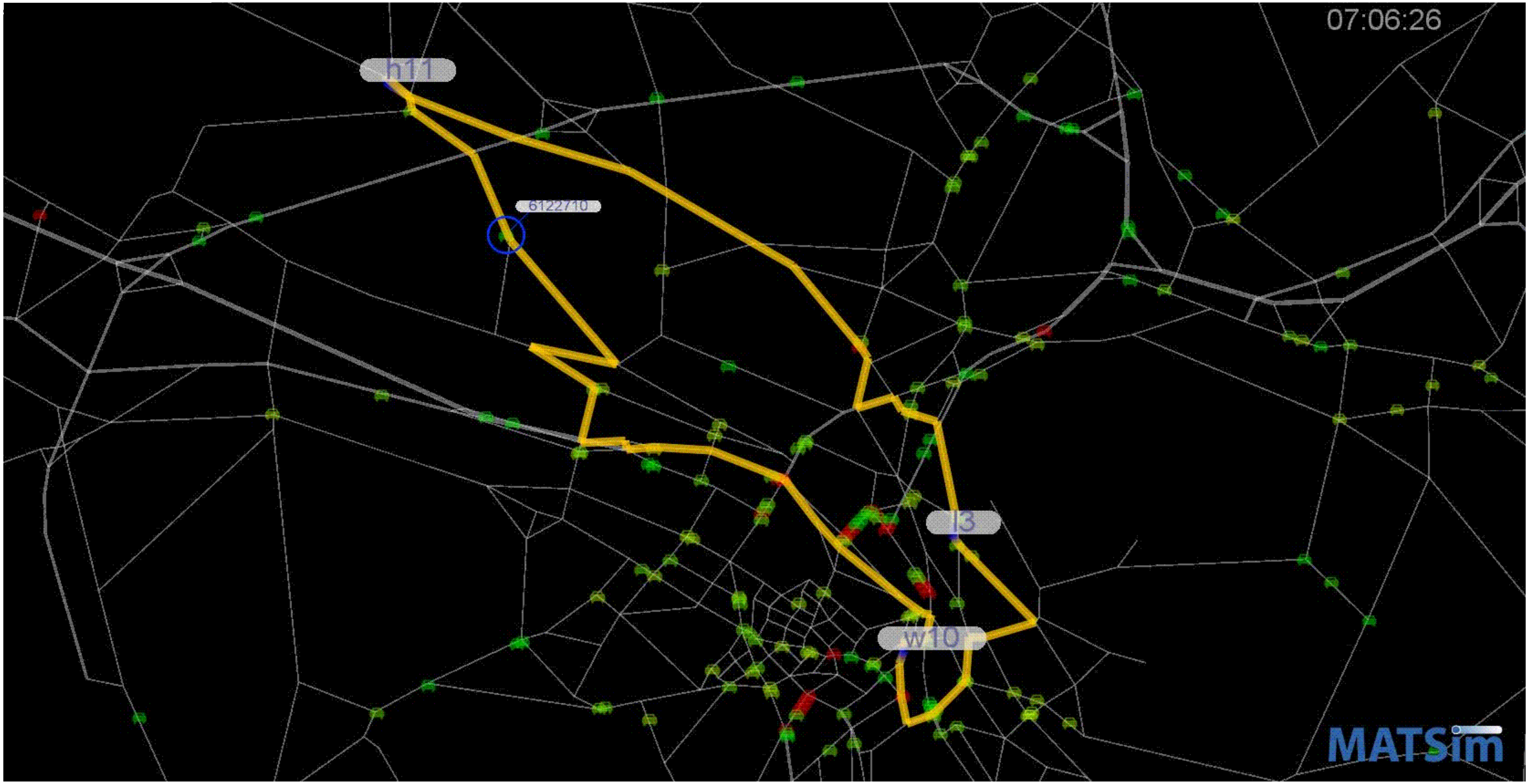
- 5.99 Mio Agents
- 1.6 Mio Facilities for 1.7 Mio Activities (5 Types)
- Navigation network with 1.0 Mio Links
- 4 Modes
- 22.2 Mio Trips
- Routes-, Time-, (Subtour-)Mode- und „Location“-Choice

➔ One Iteration in ca. 4.5 hours

Output (1)



Output (2)



PART 2: Applications

Working with MATSim…

- Users
  - Black-box use
- Super-users
  - Add new features
- Developers
  - Add new fundamental features

Current scenarios

- **Zurich and Switzerland**
  - Switzerland 7,6 Mio Agents
  - Navigation road network with 1 Mio Links
- **Berlin**
- **Munich**
- **Germany/Europe – Main road network**
  - 435 000 Links
- **Padang, Indonesia**
  - Simulation of a Tsunami evacuation
- **Tel-Aviv, Israel**
- **Gauteng, South-Africa**
- **Kyoto, Japan**
  - MATSim for the Optimization of the demand
  - Own detailed Traffic simulation with driving behavior
- **Toronto, Canada**
  - Network from EMME, Demand from TASHA
- **Caracas, Venezuela**
- **Singapore**

Current research themes (1)

- **Simulation of Public Transport**
  - Improved Routing, Multimodal Simulation
- **Replanning improvement: Planomat, Planomat X**
  - Reduce the number of iterations
  - Add other choice dimensions
- **Simulation of Traffic lights and Lanes**
  - Focus on adaptive Signal-control
- **Queue Simulation**
  - Parallelisation
- **Location Choice for Secondary Activities**

Current research themes (2)

- **Simulation with „Withinday Replanning“**
  - Simulation of Evacuations, Accidents, Parking search
- **Modelling of the vehicle fleet**
  - Calculation of emissions
- **Introduction of Land-use**
  - Integration with UrbanSim
- **Location choice of Retailers**
  - Addition of Supply-side Agents
- **Car-Sharing**
  - Carsharing as additional modal option

Example 1: Adding carsharing as modal option

Motivations & Goals

Motivations

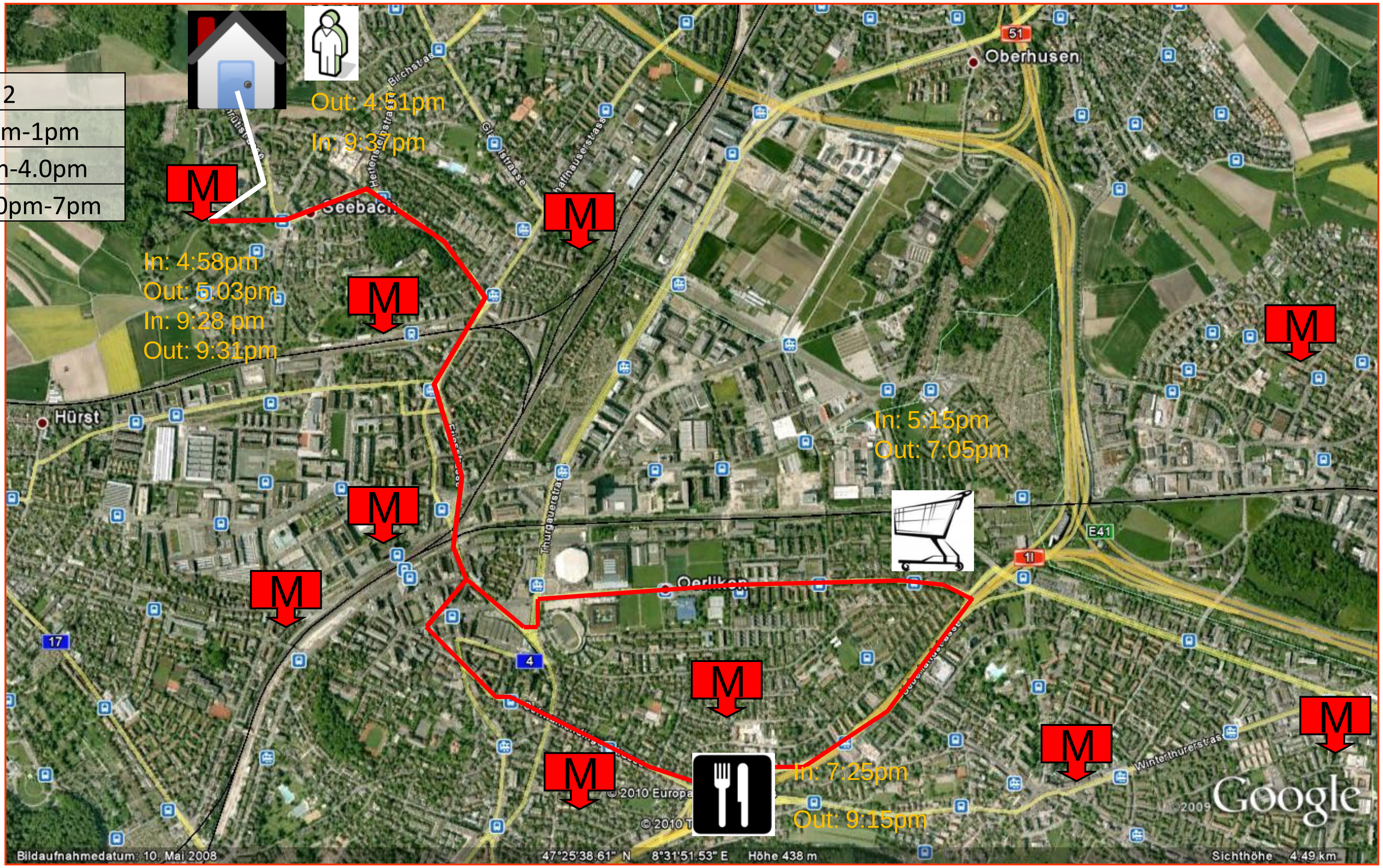
- Carsharing and shared vehicle systems are growing fast but there are no models able to predict the demand for such systems

Goals

- Introduce carsharing as new modal option for the agents
- Show that the fundamental aspects of carsharing use are captured by the model

Representation of Carsharing travel

Car 1	Car 2
8am- 9.30am	10am-1pm
12pm-14pm	3pm-4.0pm
5am-10pm	4.30pm-7pm



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

MATSim
Multi-Agent Transport Simulation

The modelled system

- The fee for carsharing is the sum of a distance fee and a time dependent fee
- Agents can pick up the cars only at predetermined locations (stations), and must bring them back to the same spot
- Agents are always choosing the closest station to the starting facility, stations are real car-sharing locations in the modeled area
- It is assumed that agents are walking to the pick-up point
- Car-sharing is available to everybody having a driving license (no membership is needed)
- An unlimited number of cars is available at the stations

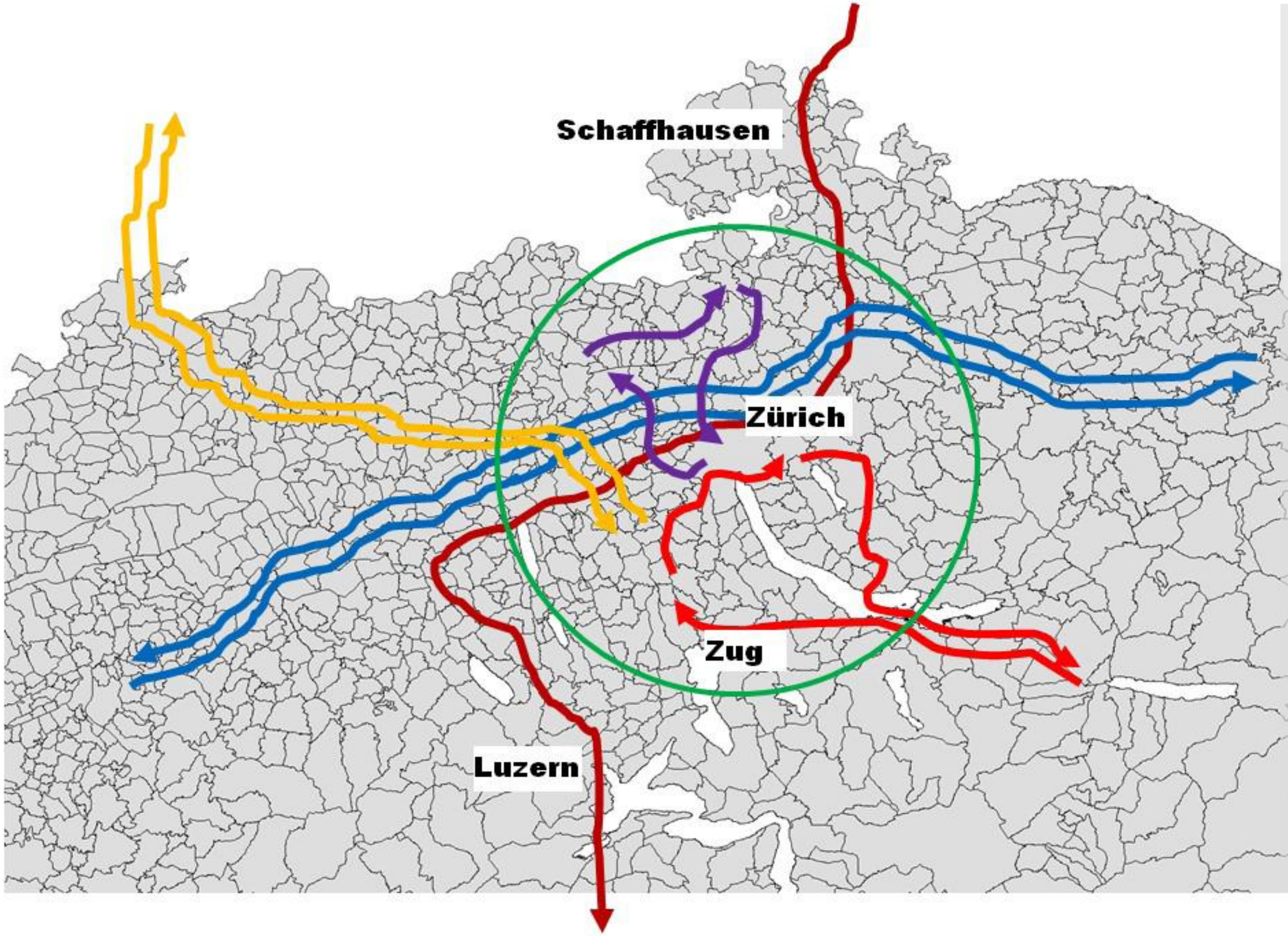
Utility Function carsharing

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

$$U_{travel,i,cs} = \alpha_{cs} + \beta_{cost,cs} Cost_t * RT + \beta_{tt,walk} * (AT + ET) + \beta_{tt,cs} * TT + \beta_{cost,cs} * Cost_d * Dist$$

- The score for a Carsharing leg is calculated as the sum of normal walk legs and a car leg with the addition of a time dependent cost term

Car Sharing Simulation: Test Scenario



Links:

236.000

Nodes:

73.000

Facilities:
373.000

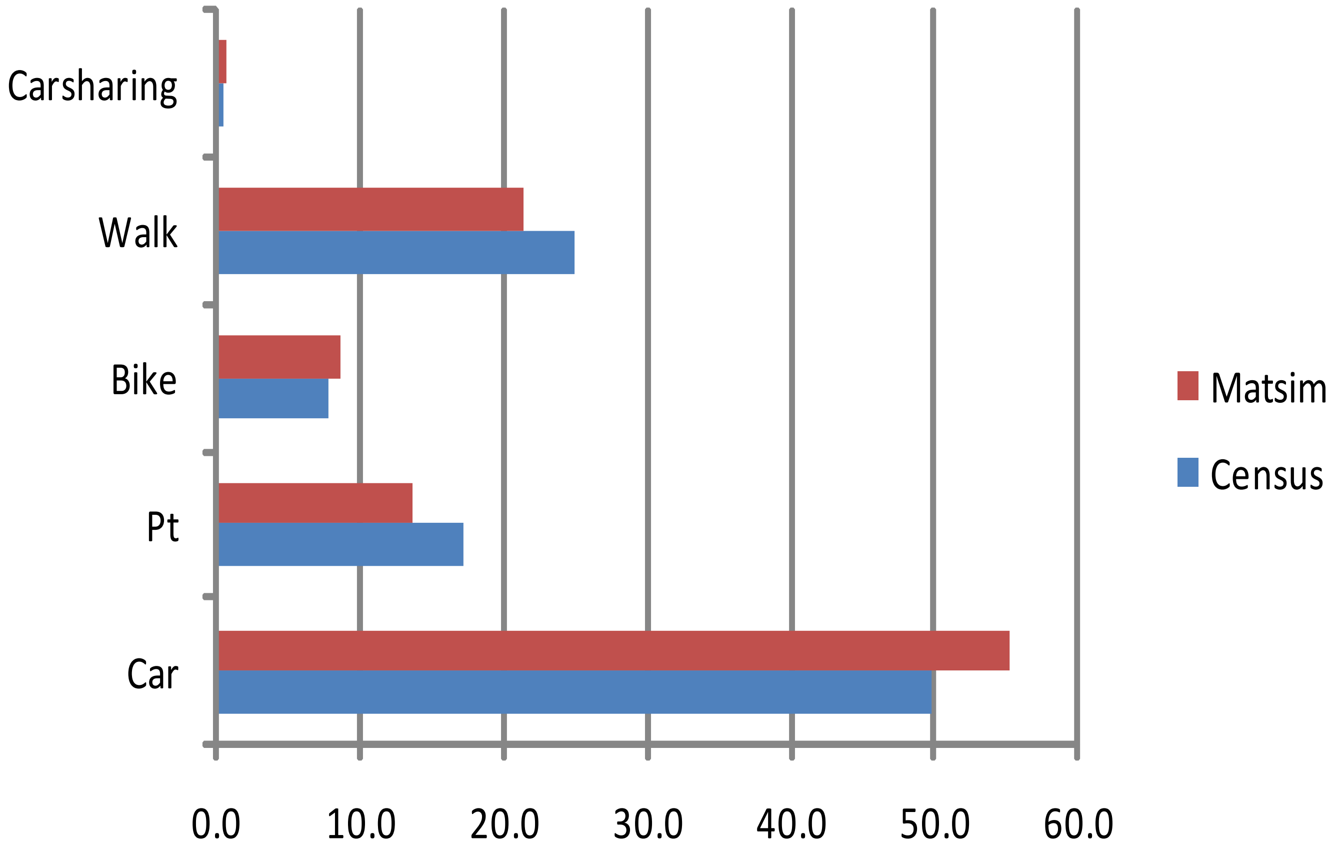
Time resolution:

1 second

Agents:

161.000 (10%)

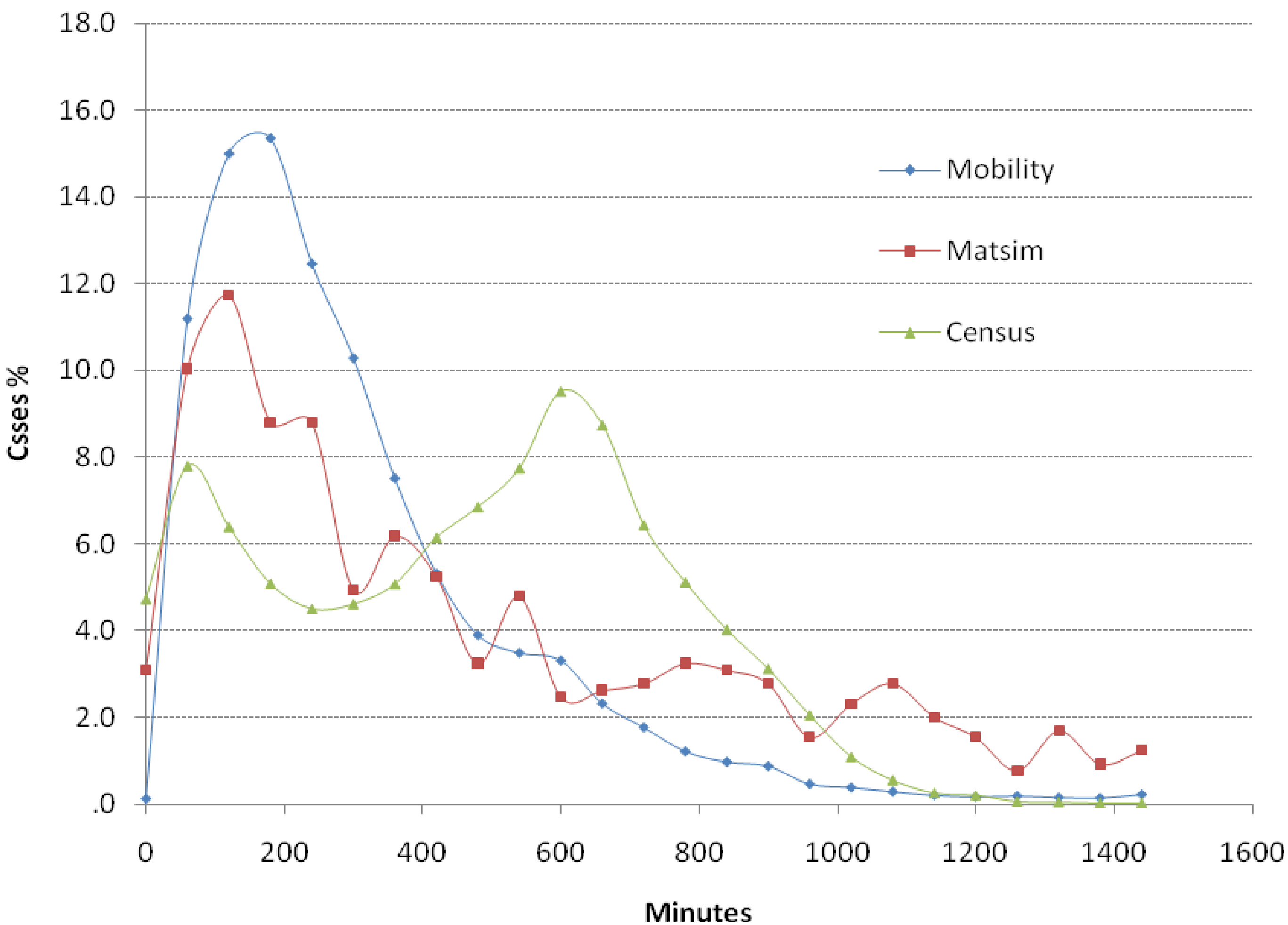
Simulation: Modal Shares



Validation with Mobility Swiss Data

- Mobility Swiss: 2350 Cars at 1200 Stations
- Data from 107 Stations in the area around Zurich and corresponding Trips and Customers data
  - Stations: Location (coords), # cars
  - Customers: Home location (coords)
  - Trips: Start and end time, distance

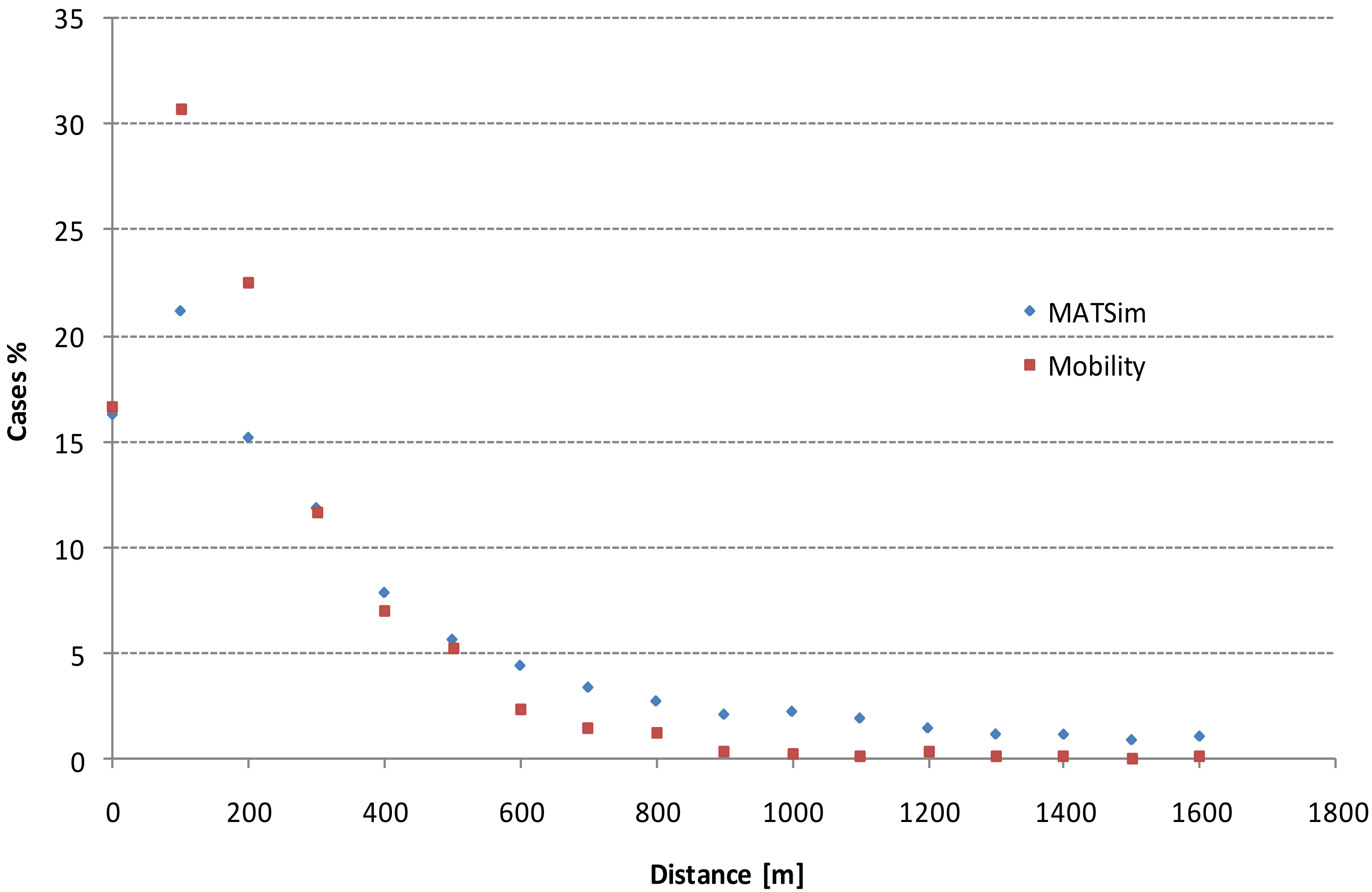
Tour duration



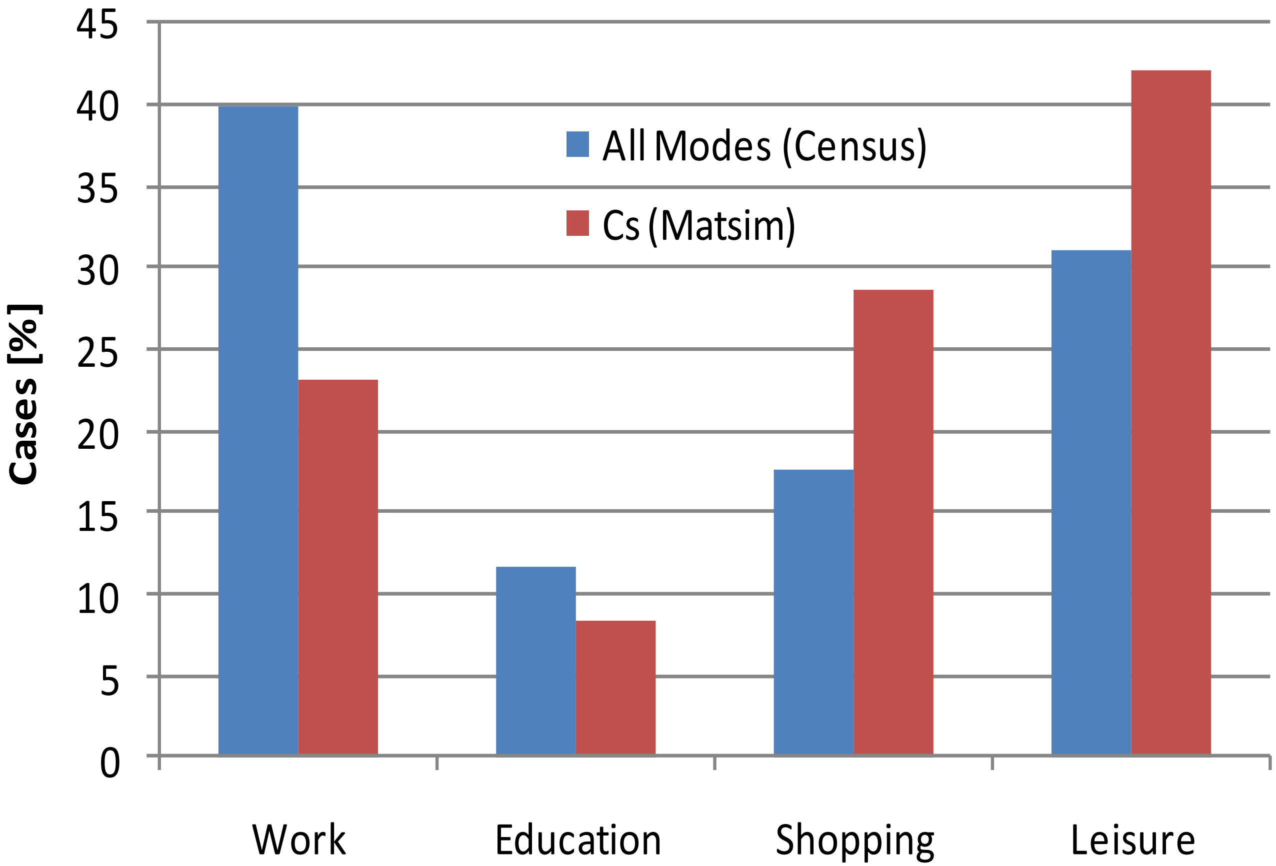
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

MATSim
Multi-Agent Transport Simulation

Distance to the station



Trip purpose



Summary

- The model is still simple, yet capable to capture some of the most important aspects of carsharing usage

Future Work:

- Access to the stations with any mode
- Limited number of vehicles at stations
- Schedule for the vehicles
- Membership model
- Refined behavioural models (Survey)
- Further Validation (Mobility customers data)

Example 2: Improving location decisions of retailers using an agent based approach

Motivations & Goals

Motivations

- To have an agent-based system which allows the **dynamic interactions** of **demand** side and **supply** side agents

Goals

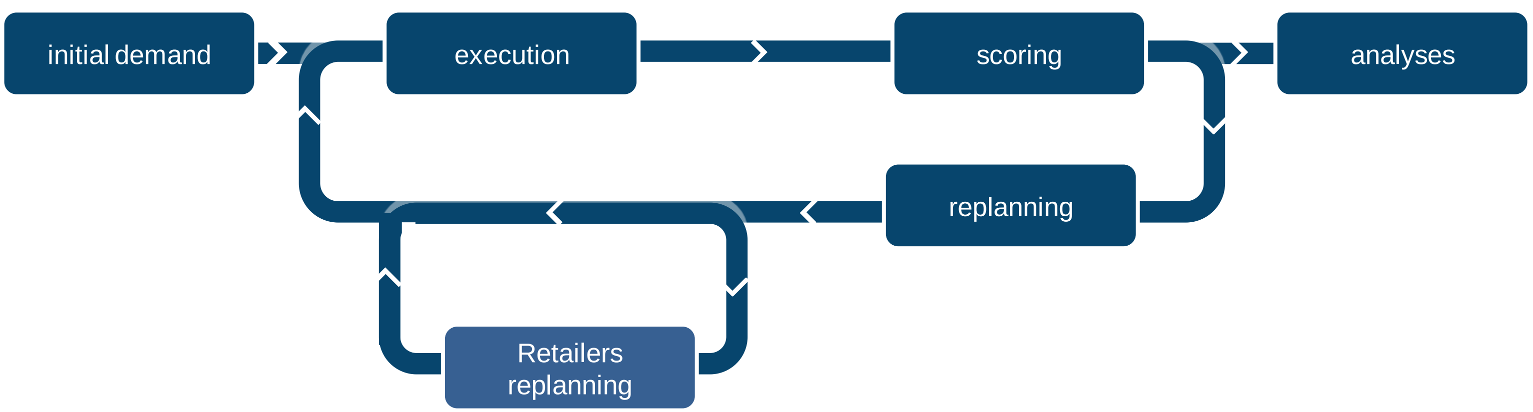
- Introduce **retail agents** which are able to relocate their stores
- Show that shops' locations can be improved with this methodology

Retail agents

Retailer: "Person or entity having the control on one or more shopping facilities (retail stores)"

Goal: Maximize the number of customers

Choice dimension: Location of retail stores



ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

MATSim
Multi-Agent Transport Simulation

Relocation

Each retailer uses a **genetic algorithm** with the following objective function:

$$\min \sum_{i}^{n} \left(\frac{\sum_{j}^{m} c_{ij}}{m} \right)$$

n = number of shops of the considered retailer
m = the number of potential customers for the shop i at the given location
c_{ij} = generalized cost of travel for the individual agent *j* to travel to location *i*

Simulation Scenario

- Area around Zurich

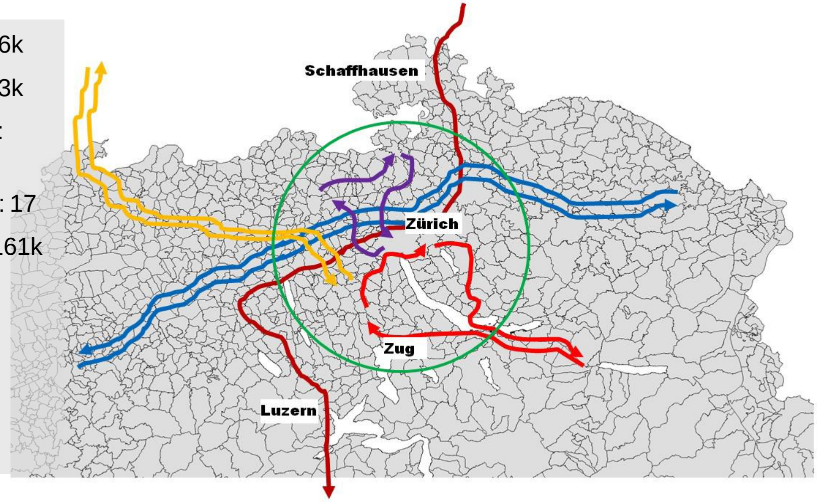
Links: 236k

Nodes: 73k

Facilities: 373k

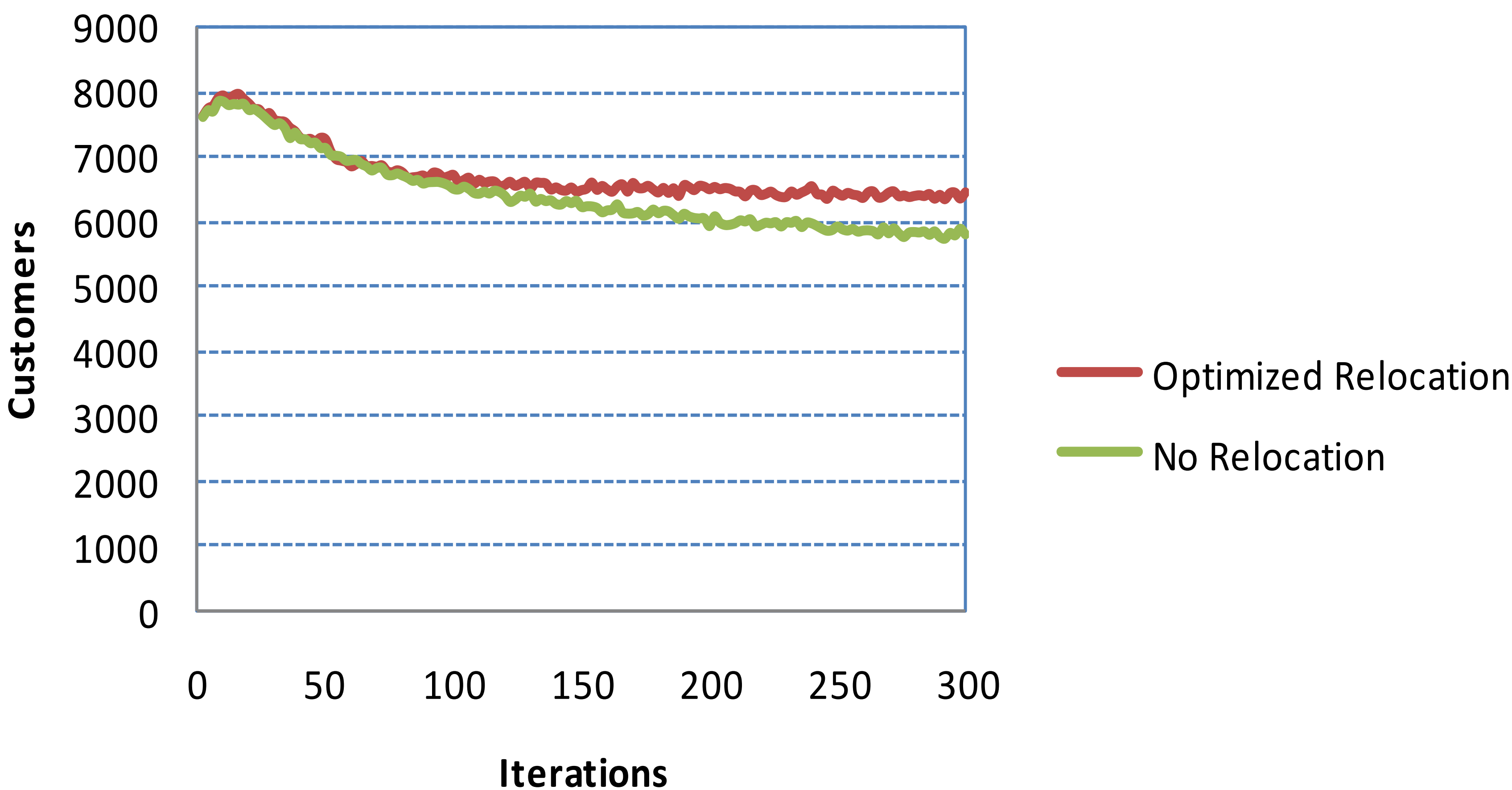
Activities: 17

Agents: 161k (10%)



- Two retailers, with respectively 29 and 17 stores
- Initial locations of **two real Swiss retailers**, leaders in the grocery market.
- Locations available have been selected randomly, but accepted under some specific requirements. For each candidate location, an hypothetical caption area around it has been considered.
  - Potential customers above a given threshold in the area
  - Ratio potential customers/ shops capacity above a given threshold

Results (1)


9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Customers
0
50
100
150
200
250
300
Iterations
Optimized Relocation
No Relocation

Results (2)

	Retailer 1	Retailer 2
Number of Shops	29	17
Stores Moved	12	6
Stores Moved %	41%	35%
Customers (Move)	3541	2902
Customers (No move)	3199	2603
Increase %	10.6%	11.4%

Summary

- Retail agents in the simulation are able to increase the number of their customers by relocating their shops

Future work:

  - Validation regarding the number of customers shopping in specific stores
  - Run 100% Scenario
  - Further agent types (transport operators, planners, public authorities, legislators, etc.)

PART 3: To conclude...

MATSim Summary

- Agents are software abstractions representing persons acting in an artificial world
  - Personal attributes/behavioural rules
  - Goal-oriented
  - Learning ability (experience)

- They are traveling as a consequence of individual needs (shopping, work, leisure, etc.)

- Agents are competing for the infrastructure

- Iteratively (one day is iteratively simulated) until a steady state is reached.

Key Features

- **Fast Dynamic and Agent-Based Traffic Simulation**
  Uses a dynamic assignment and simulate whole days within minutes
- **Private and Public Traffic**
  Both private cars and transit traffic can be simulated
- **Supports Large Scenarios**
  MATSim can simulate millions of agents and/or huge, detailed networks
- **Versatile Analyses and Simulation Output**
  E.g. compare simulated data to real-world counting stations
- **Modular Approach**
  Easily extended with your own algorithms
- **Interactive Visualizer**
  See what each agent is doing during the simulation
- **Open Source**
  You get the Java Source Code, which runs on all major operating systems
- **Active Development**
  We add constantly new features and improve current ones

Team

- **ETH Zürich, IVT**
  - Prof. Dr. Kay W. Axhausen
  - Dr. Michael Balmer
  - Francesco Ciari
  - Christoph Dobler
  - Andreas Horni
  - Kirill Müller
  - Dr. Nadine Schüssler
  - Basil Vitins
  - Rashid Waraich
- **TU-Berlin, VSP**
  - Prof. Dr. Kai Nagel
  - Yu Chen
  - Dominik Grether
  - Johannes Illenberger
  - Benjamin Kickhöfer
  - Gregor Lämmel
  - Andreas Neumann
  - Thomas Nicolai
  - Michael Zilske
- **Senozon AG**
  - Dr. Michael Balmer
  - Dr. Marcel Rieser

- THANK YOU FOR YOUR ATTENTION !

- MATSim project: www.matsim.org