# Preferred citation style

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# MATSim: Status report on an agent-based micro-simulation toolkit

KW Axhausen

IVT
ETH
Zürich

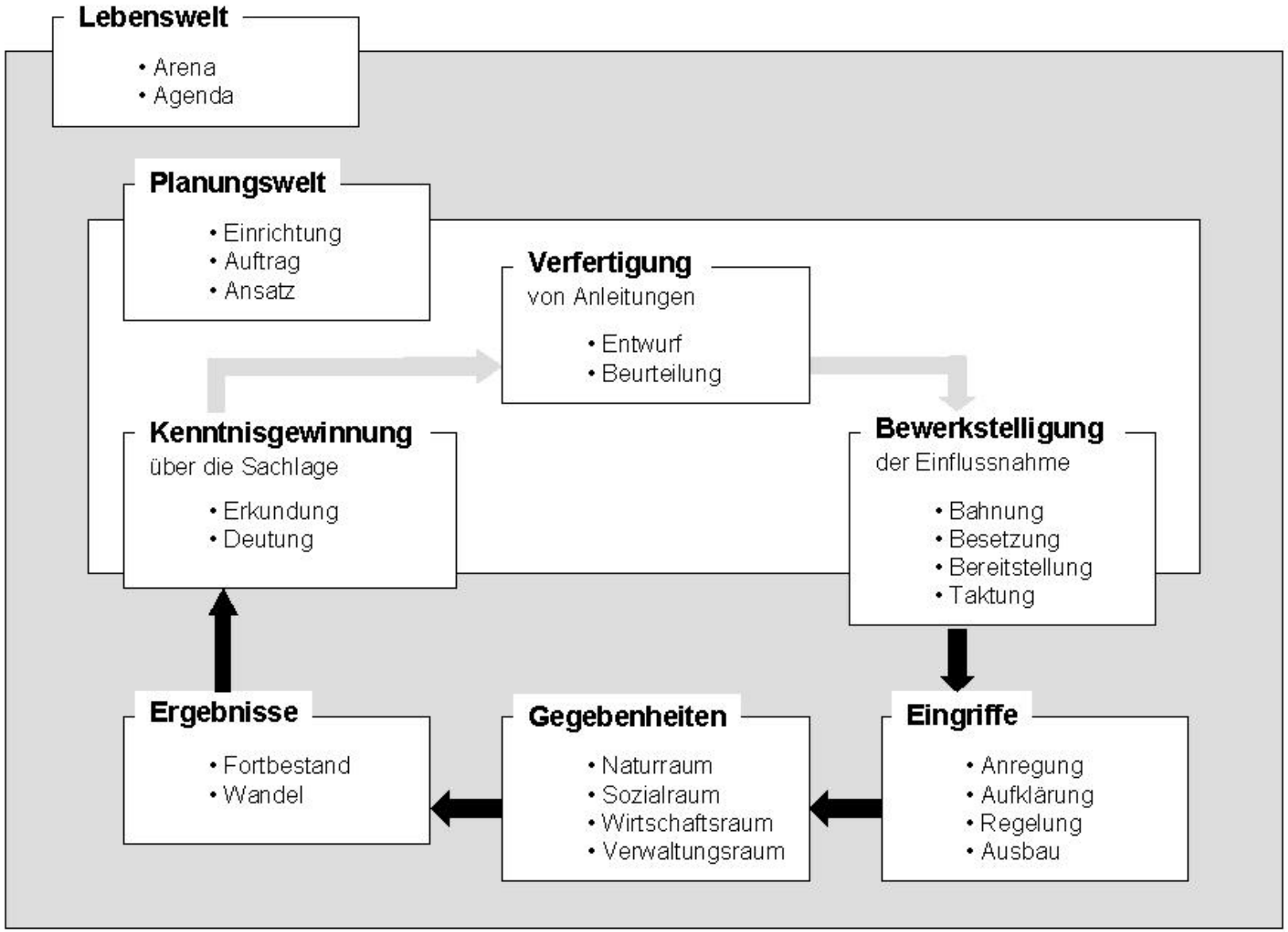
Januar 2010

Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

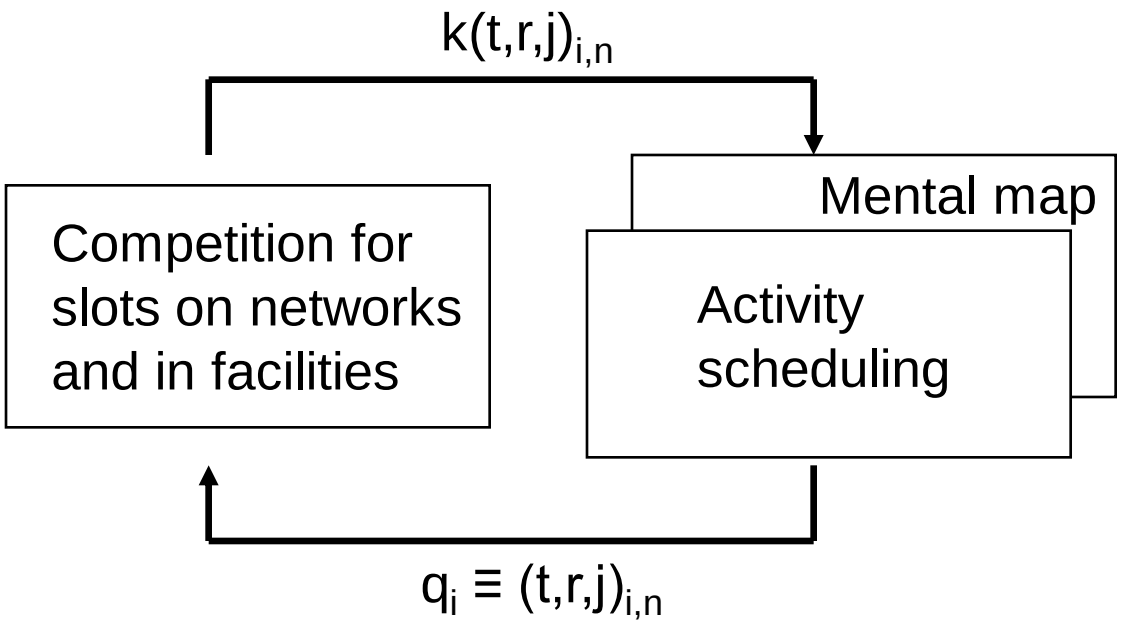
# Starting point

# Why (agent-based) simulation ?




Heidemann, 1992

# Learning approach of the generic transport model



# Possible equilibria

| | Perfect knowledge | Imperfect knowledge |
|---|---|---|
| Average user cost | Deterministic user equilibrium | **Stochastic user equilibrium** |
| Social cost | System optimum | |

# Full sets of requirements

# Traffic flow simulation

- Disaggregate simulation of car traffic
  - Detailed traffic control
  - Detailed parking facilities
  - Detailed recharging facilities for electric vehicles
- Disaggregate simulation of public transport
- Disaggregate simulation of cyclists
- Disaggregate simulation of pedestrians

# Activity scheduling

- 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

# Relevant individual long(er) term choices

- Social network geography
- Social commitments
- Amount and type(s) of occupation

    - Work location(s)
    - School location
    - Home location

        - Mobility tools
        - Discount cards
        - Season tickets
        - Vehicles (by body type, fuel, energy efficiency)

# Relevant supply side long(er) term choices

- Facility construction
- (Transport) infrastructure provision
- Regulation of production
- Regulation of markets
- Regulation of migration

    - Location of production and service firms
    - Delimitation of markets served
    - Choice of the type of service or good offered

        - Capacity choice
        - Area wide signal control optimisation
        - Pricing

# MATSim: A GNU public licence software project

Main partners

- TU Berlin (Prof. Nagel)
- ETH Zürich
- Axon Active (Dr. Balmer, Rieser)

Coordination via:

- User meeting
- Developer meeting

Help for new users

- Tutorial (e.g. Mai 2010)
- www.matsim.org

# Challenges 1

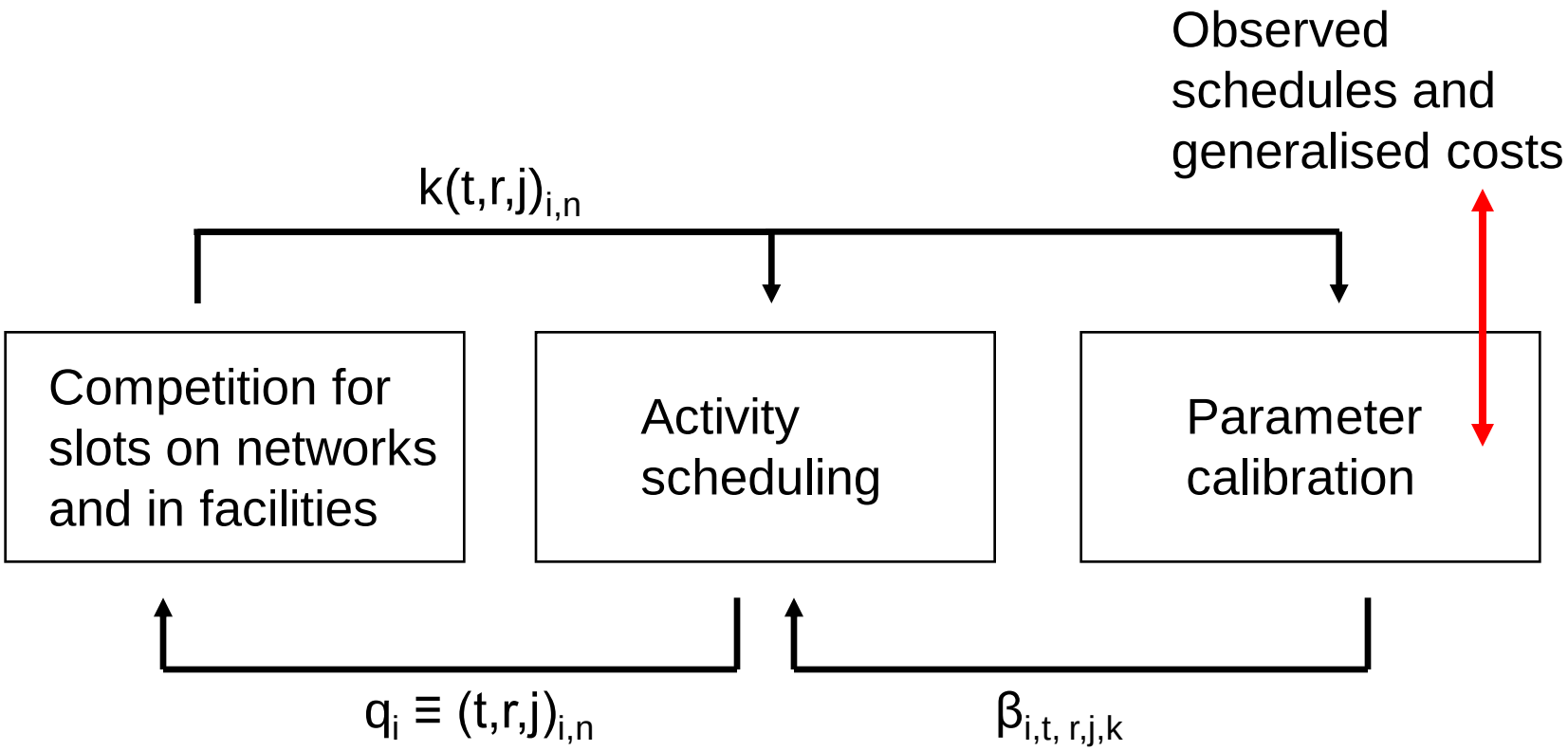
How to find the equilibrium ?

The point in the joint search space, when no agent can unilaterally improve its situation by changing its behaviour

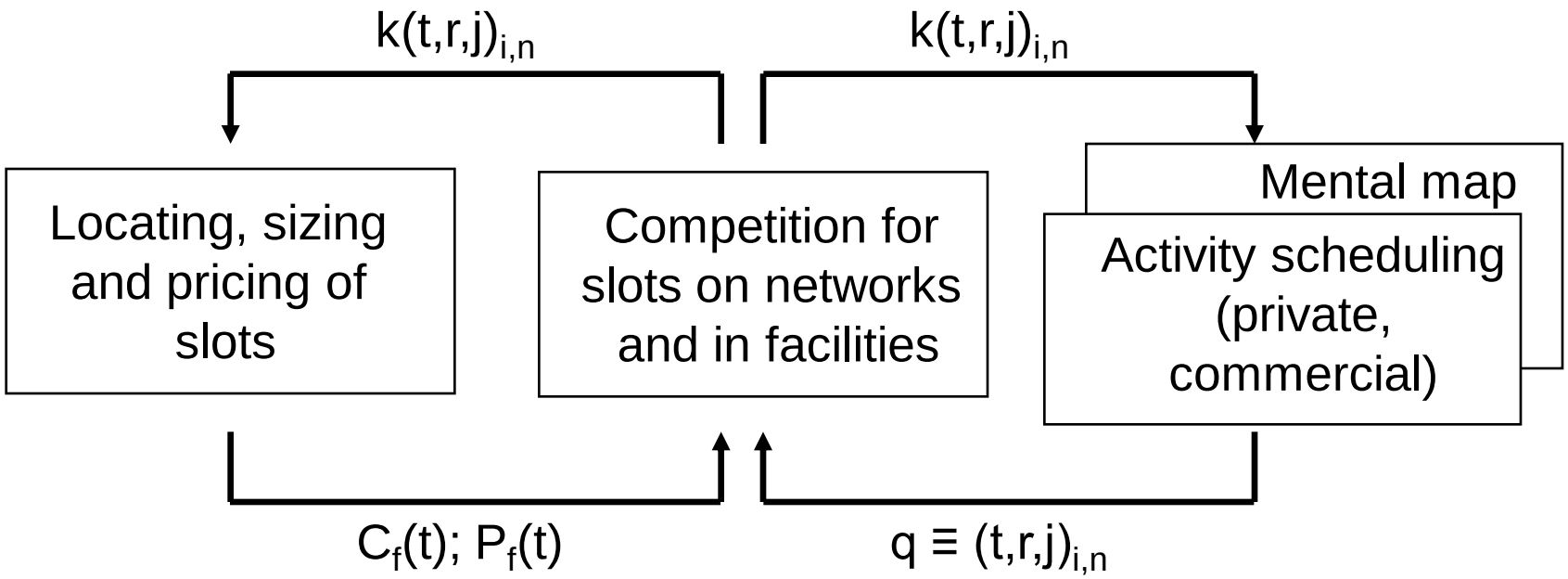
How to find it fast enough to be useful ?

Claim: The overnight policy run is fast enough (for now)

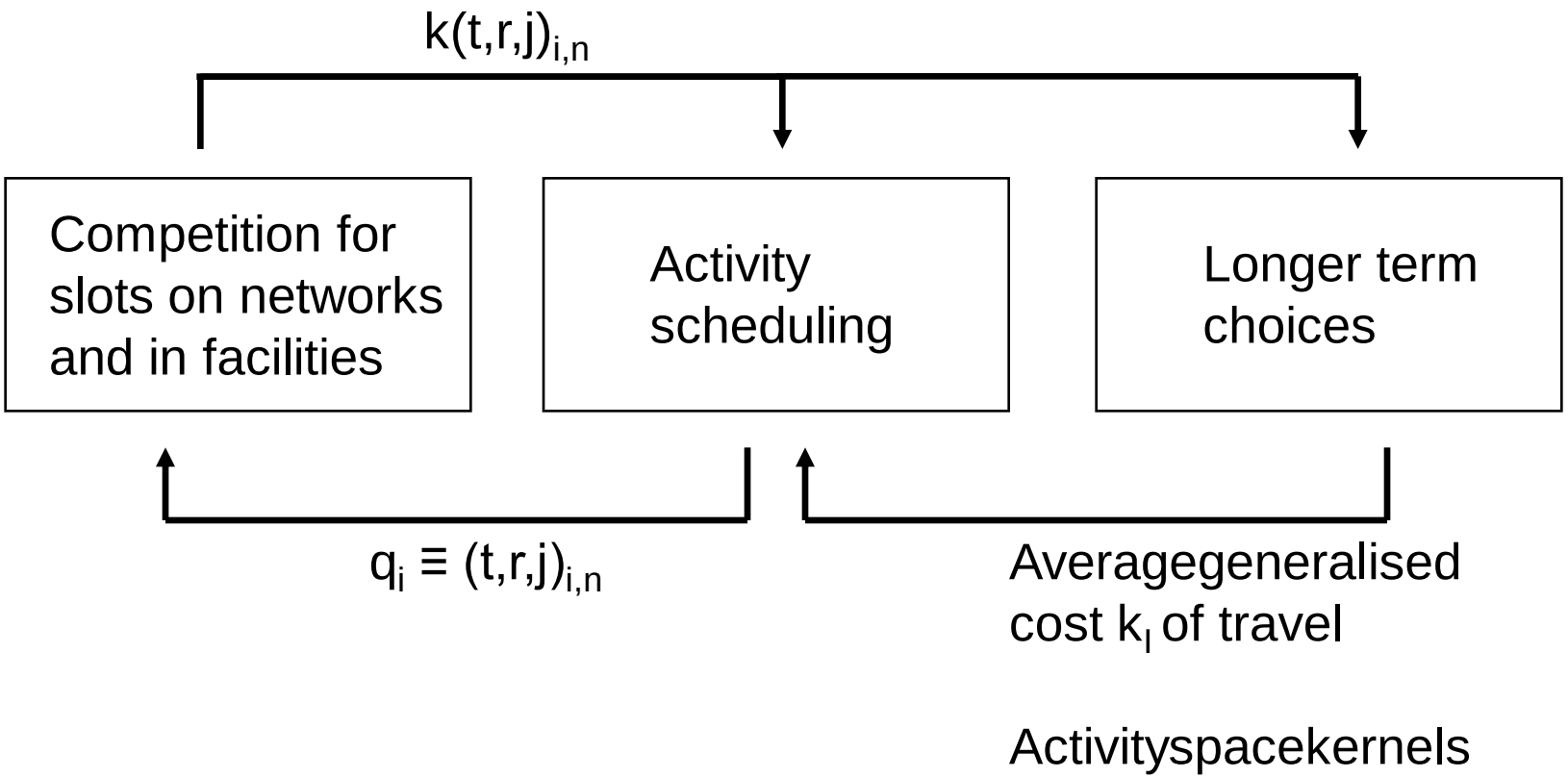
# Which equilibrium ? With parameters ?



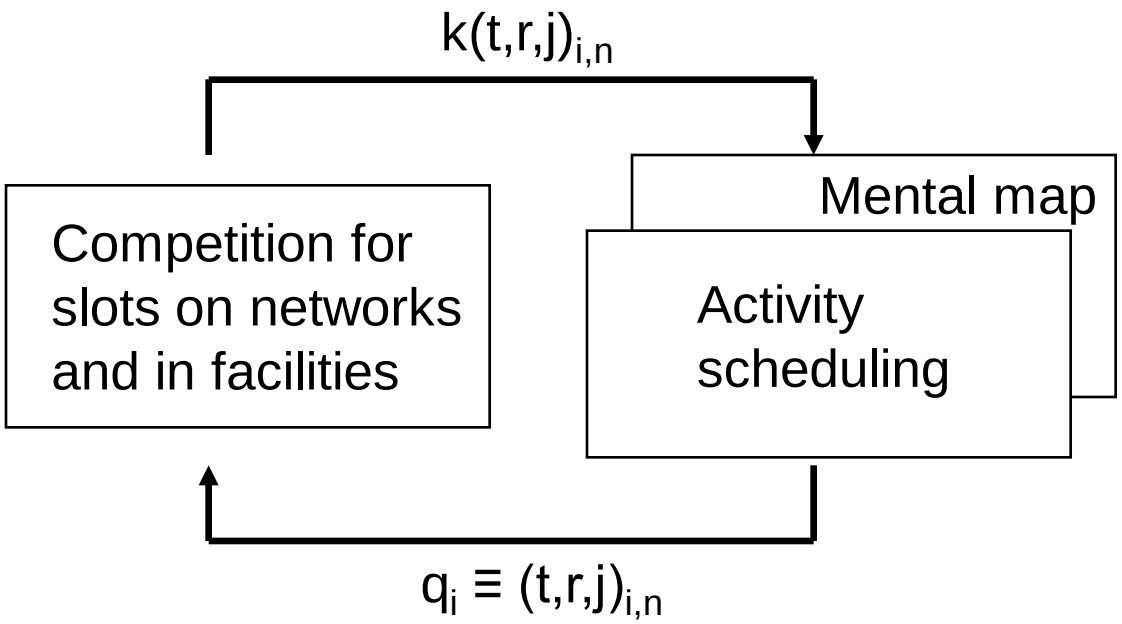
# Which equilibrium ? With prices and capacities?



# Which equilibrium ? With longer term individual choices ?



# or just: a simple, if extended „Wardrop“ equlibrium



# MATSim today

# MATSim evolutionary process

Read scenario

Generate initial demand (schedules)

Do until convergence

- Select schedule to execute with a biased random approach
- Execute schedules (traffic flow simulation)
- Score all schedules
- Add a new schedule to a random subset of the agents
- Delete worst schedule, if necessary

# Current Vickrey-type utility function

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

$$U_{act,i} = U_{dur,i} + U_{late.ar,i}$$

# 2009 MATSim: Initial demand

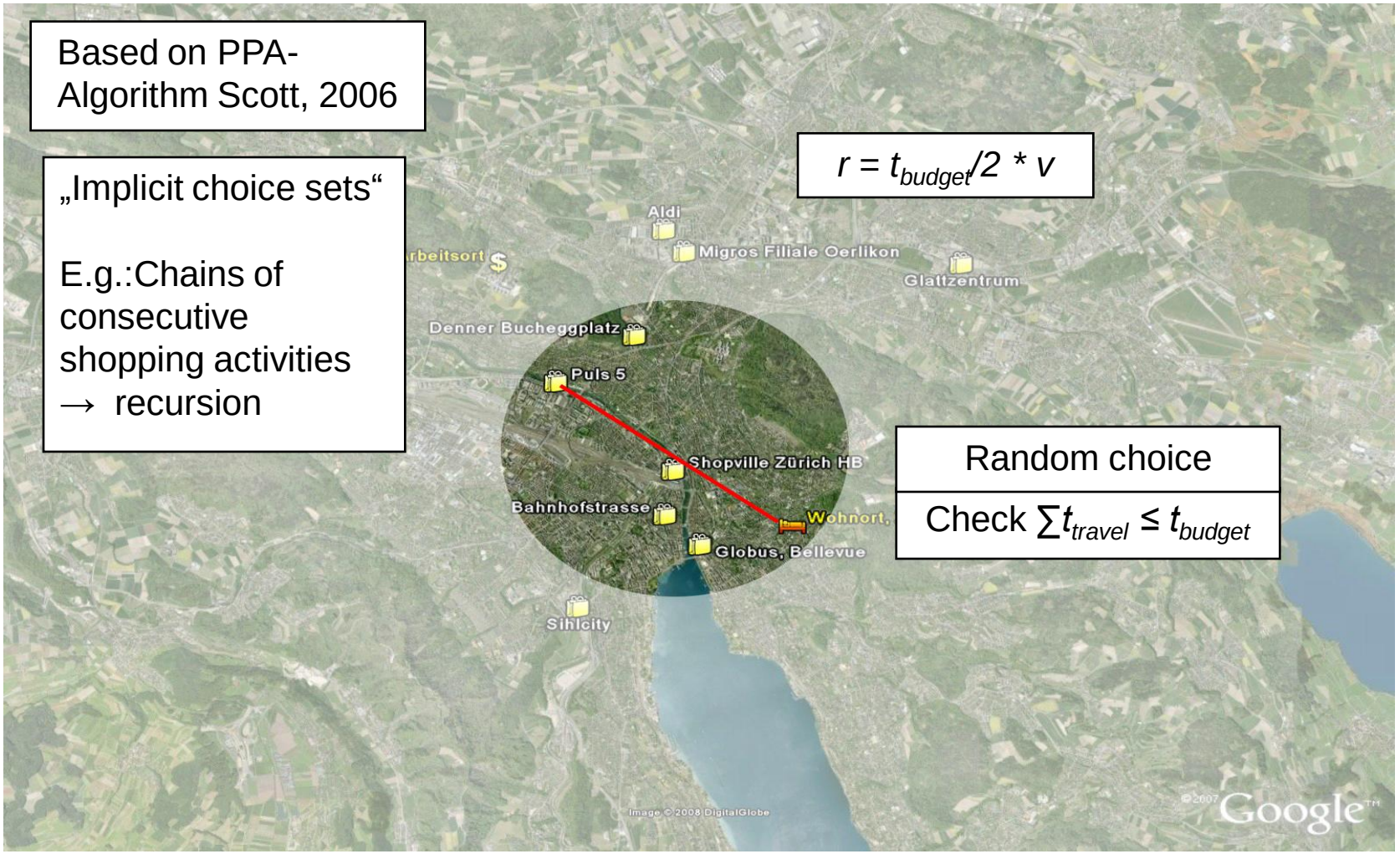
Population: Census-based (sample); Through traffic from surveys

- Number, type, sequence and duration of activities:
  - Conditional random draw from observed categorised MZ 2000-2005 distributions by person type

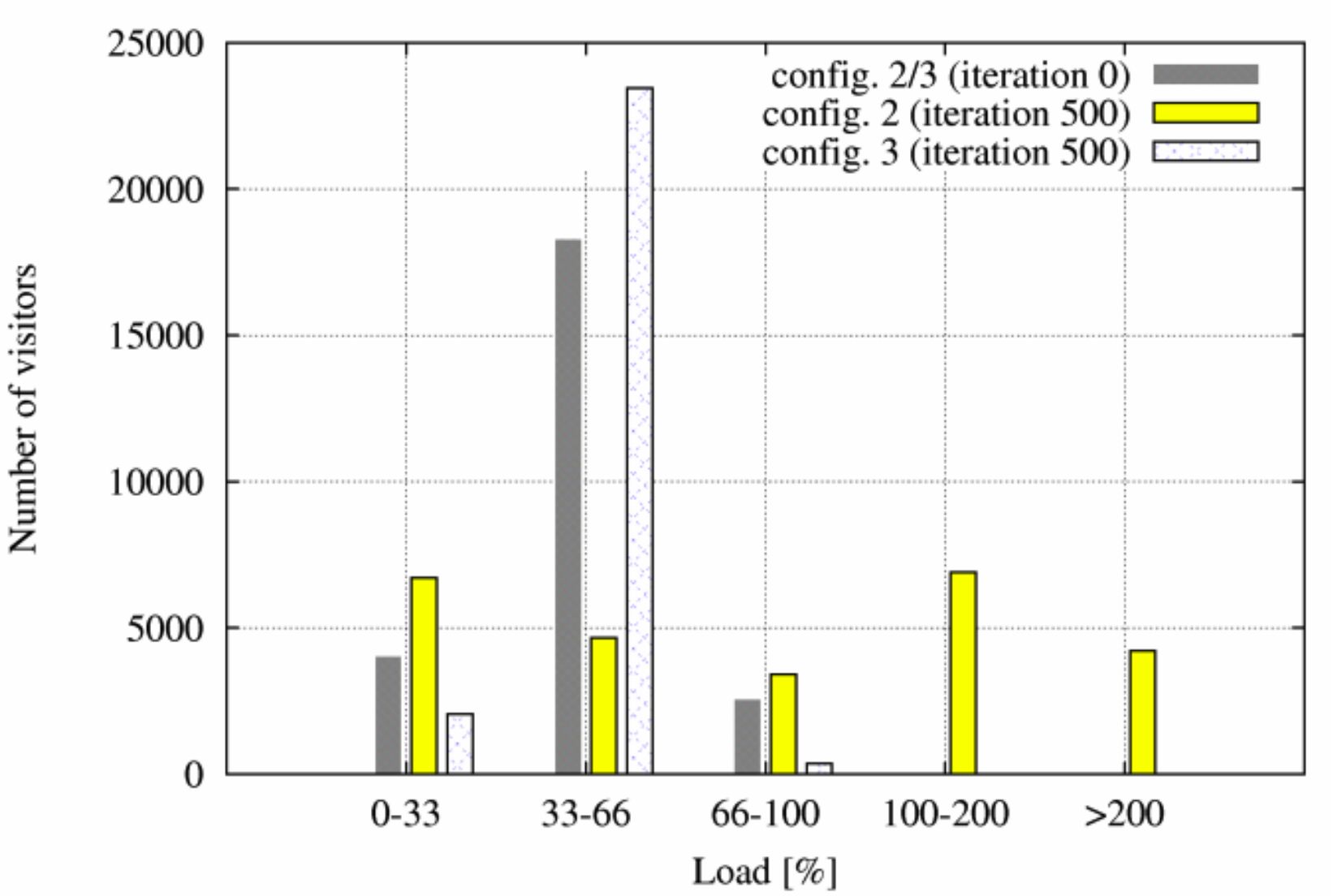
  - Location of work/school activity:
    - Census commuter matrix
  - Location of secondary activities:
    - Random constrained selection or
    - Capacity-constrained MNL within a time-space prism

    - Mode choice:
      - MZ-based subtour MNL
    - Route choice:
      - Improved A* shortest path

# Capacity constrained MNL with time-space prism

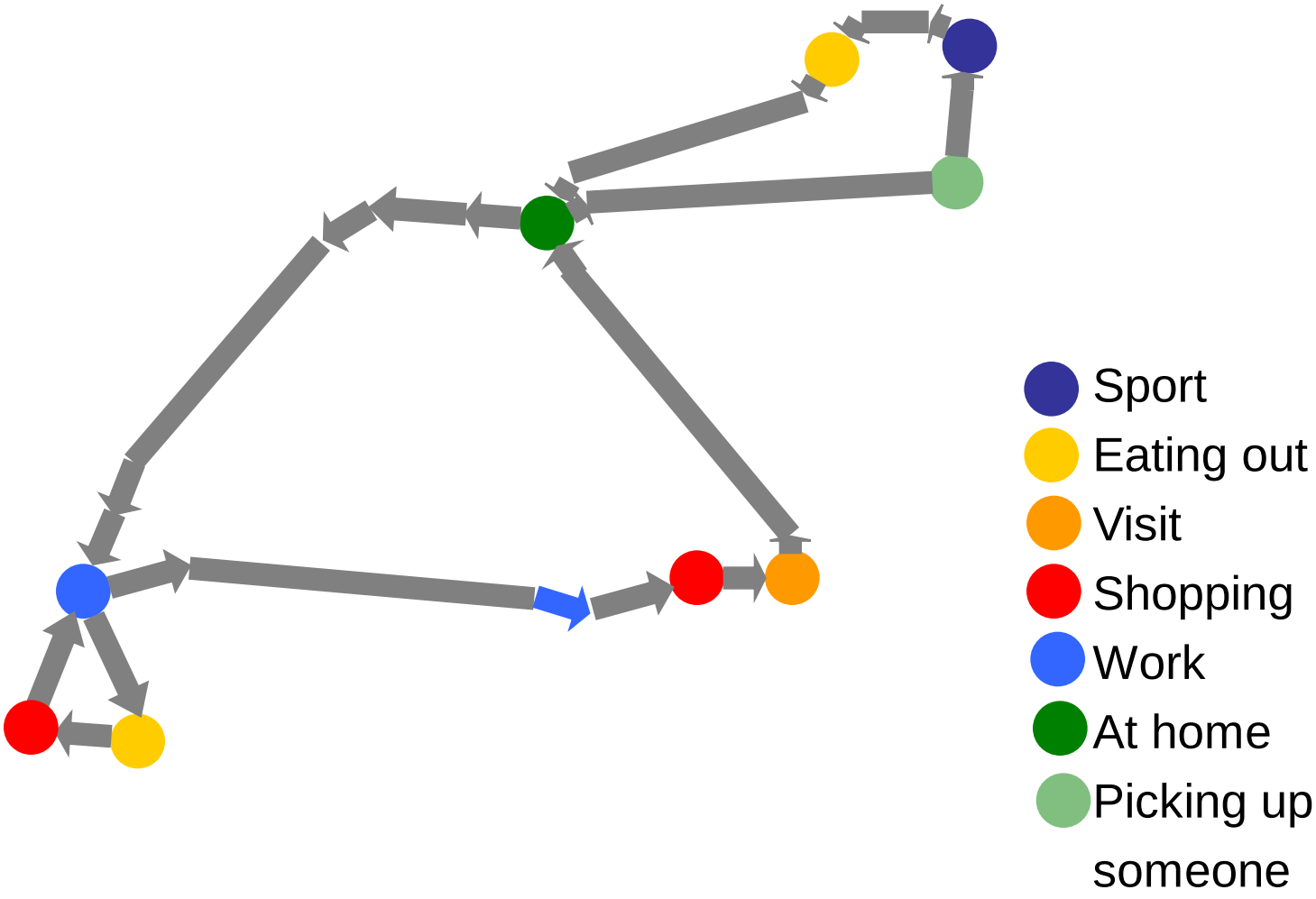


# Capacity constrained MNL with time-space prism

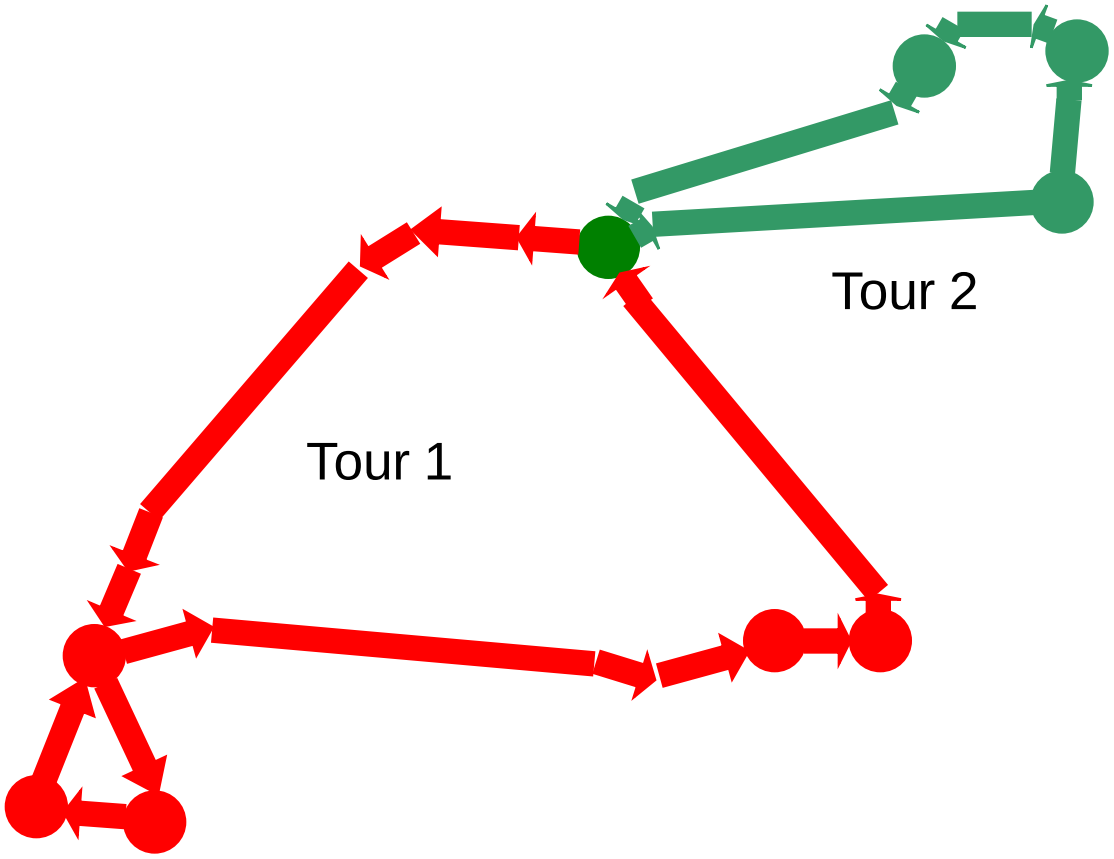



Config 2/3 without/with capacity restraint

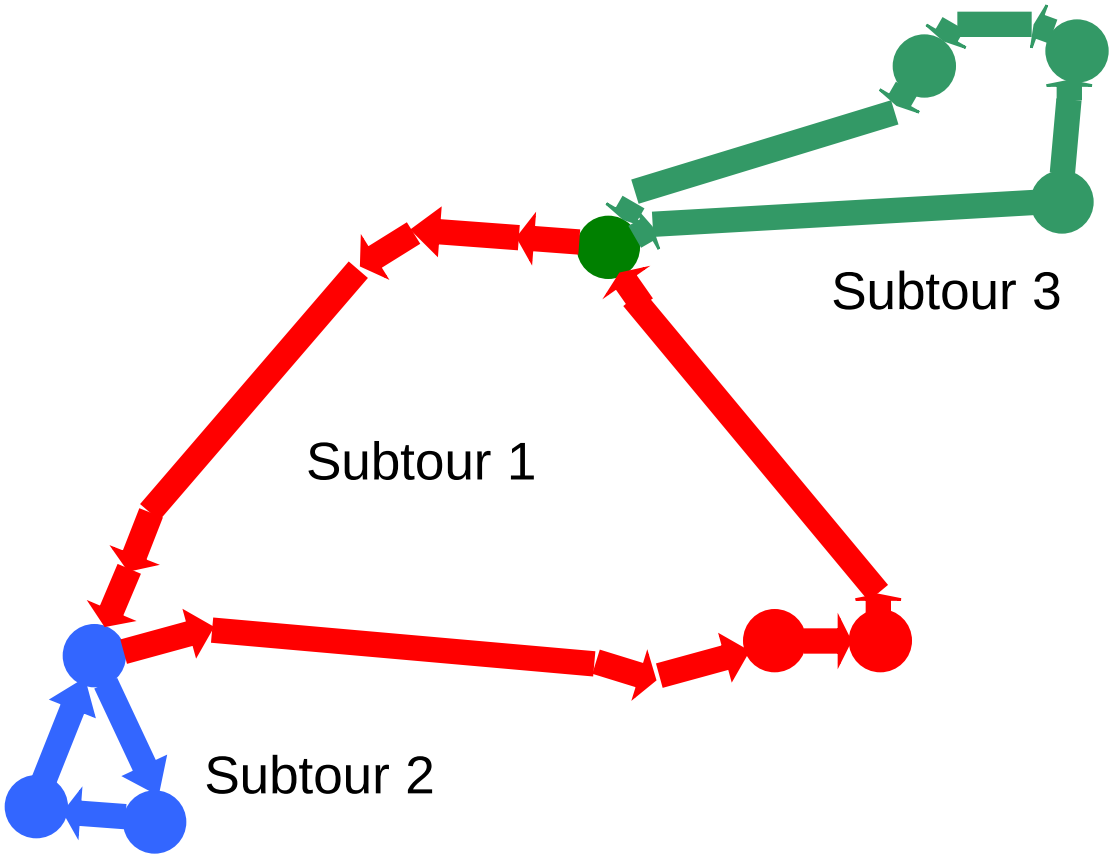
# Mode choice: Daily activity chain by type



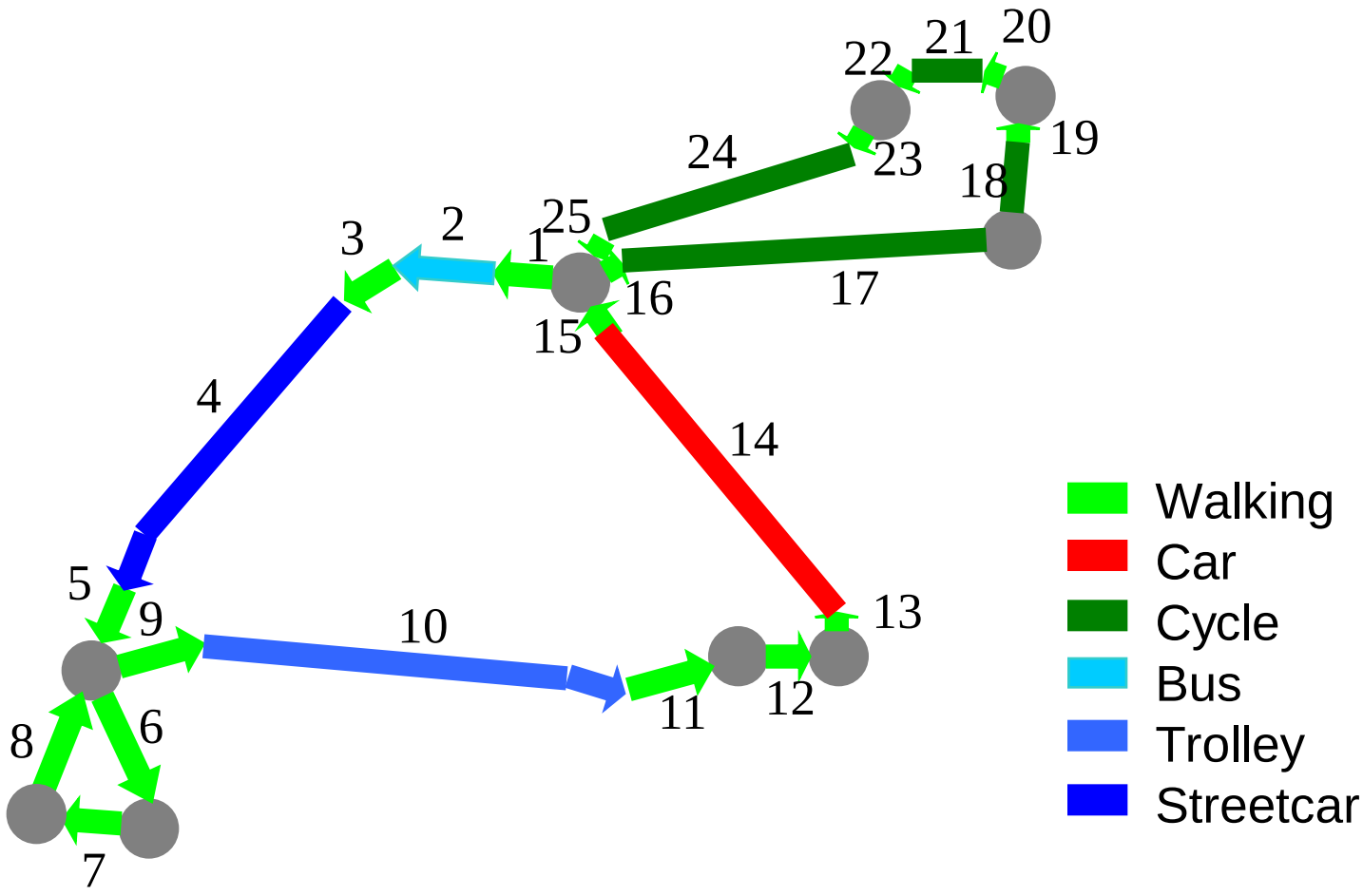
# Mode choice: Tour (journey)



# Mode choice: Subtour



# Mode choice: Daily activity chain by stage and mode



# 2009 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: Traffic flow simulation

- Disaggregate simulation of car traffic
  - Detailed signal control
  - Detailed parking facilities
  - Detailed recharging facilities for electric vehicles
- Disaggregate simulation of public transport
- Disaggregate simulation of cyclists
- Disaggregate simulation of pedestrians

# Java - queue-based traffic flow simulations

| Approach | Number of cores | Signals | Public Transport |
|---|---|---|---|
| Event | Parallel | No | Pseudo |
| Event | Parallel | No | Zonal travel time matrices with transit stops |
| Event | Single | No | Pseudo |
| Time step | Single | No | No |
| Time step | Single | No | Pseudo |
| Time step | Single | No | Micro (driver; passengers) |
| Time step | Single | Yes | No |

# Modelling Switzerland 2009

# 2009 MATSim Switzerland: Configuration

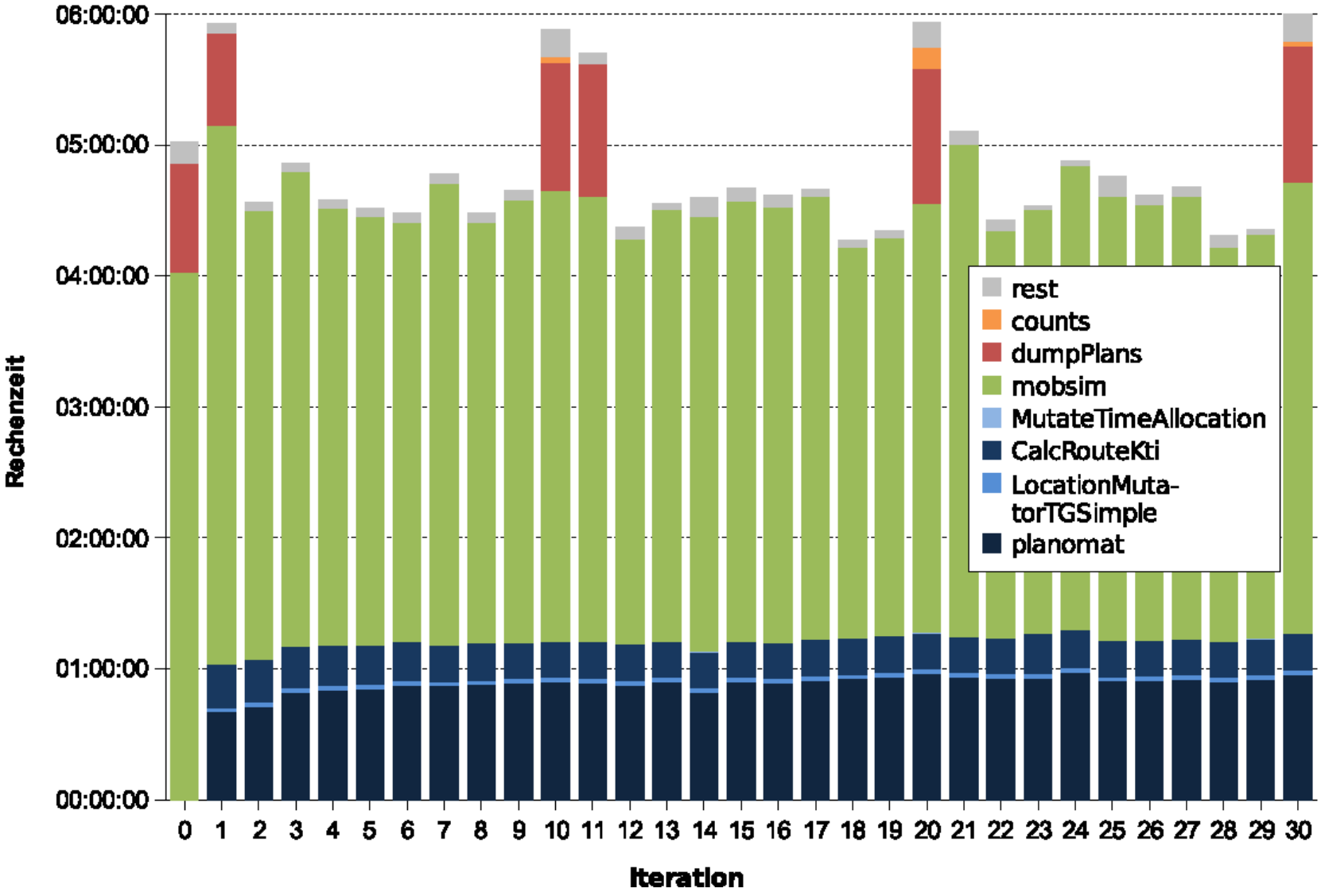
During the iterations:

- 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:

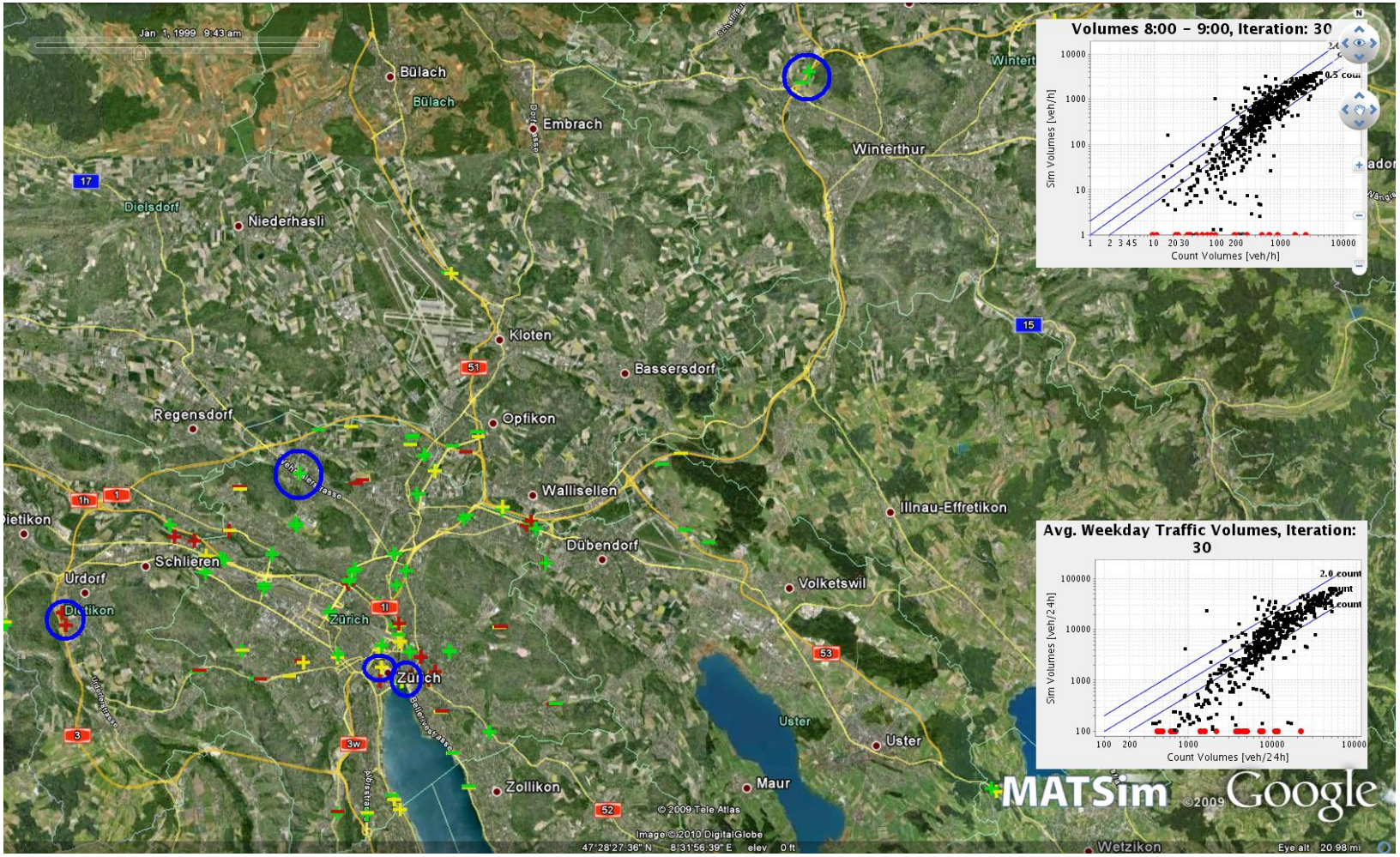
- $6.0 * 10^6$ agents with 11 activity types
- $1.6 * 10^6$ facilities
- $0.8 * 10^6$ links
- 24 * 60 * 60 seconds

# 2009 MATSim Switzerland: Computing time

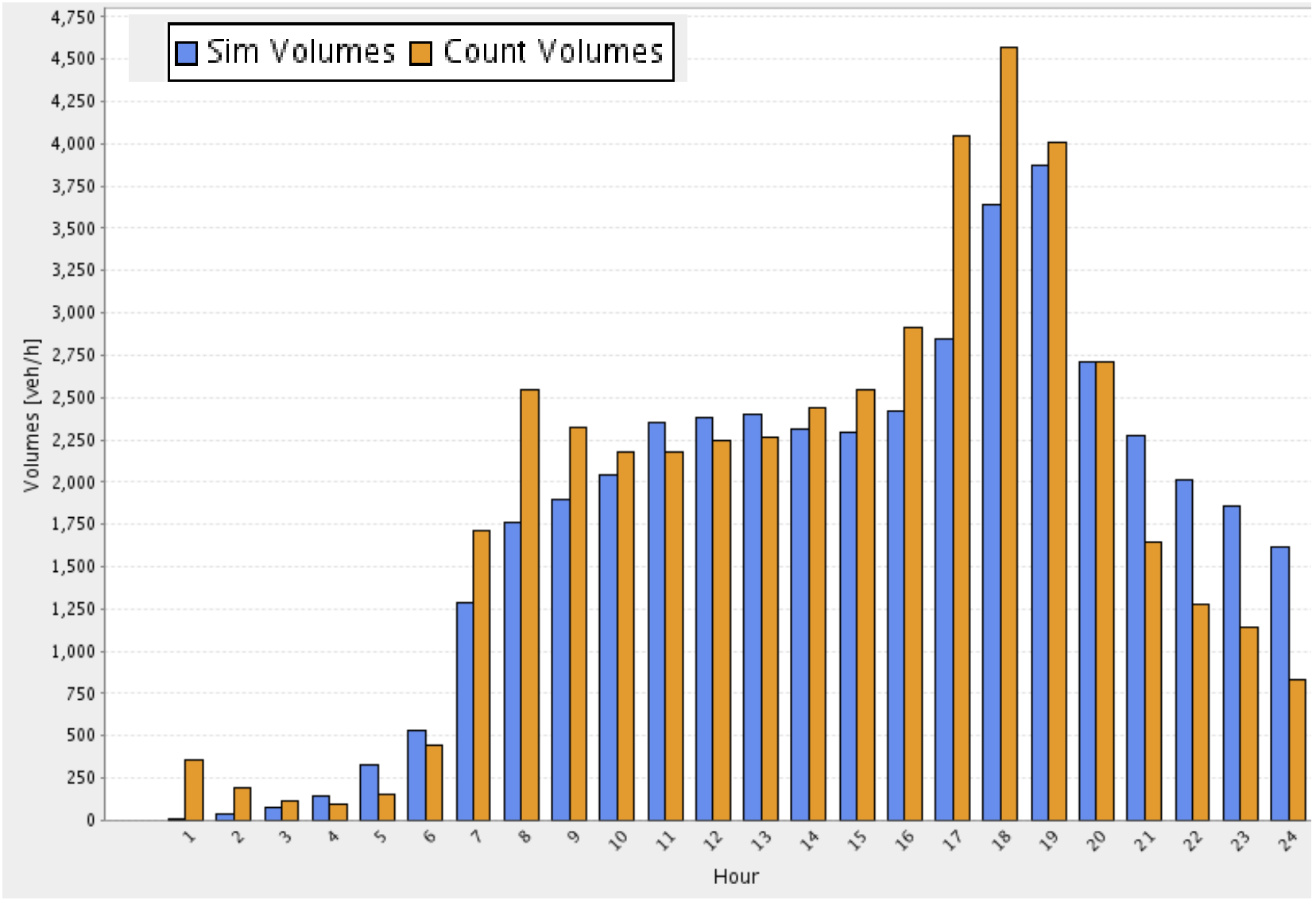



Balmer, 2009

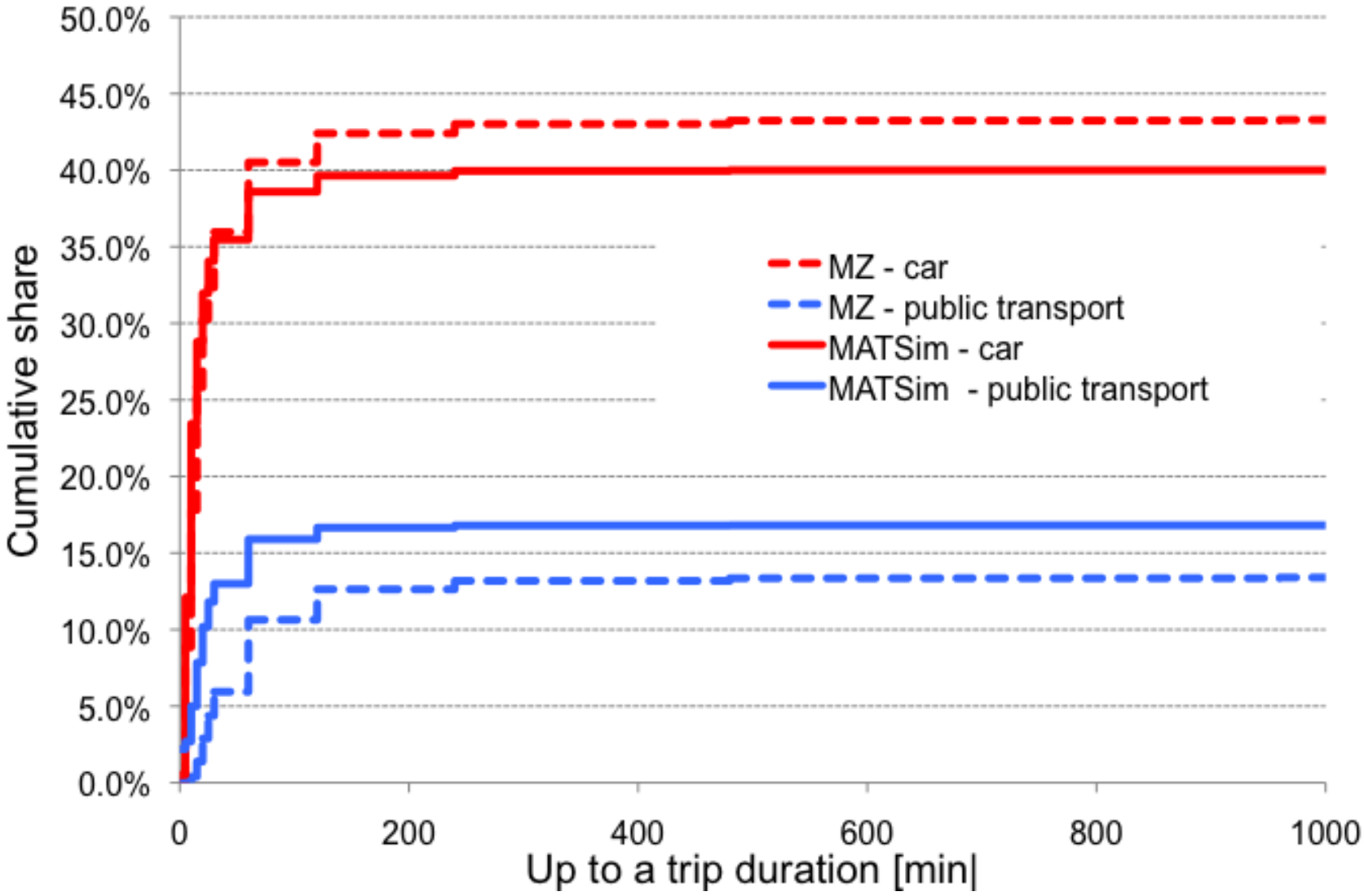
# Quality of the results: Overall counts



# Quality of the results: A1 at Winterthur (no transit traffic)



# Quality of the results: 2 of 5 modes



# Next steps

# 2010 MATSim configuration of traffic flow simulation

- **(Parallel) queue based simulation(s) of car traffic**
  - Detailed traffic control
  - Detailed parking facilities
  - Detailed recharging facilities
- **Vehicle – timetabled based simulation of public transport**
- Disaggregate simulation of cyclists
- Disaggregate simulation of pedestrians

# 2010 MATSim configuration of activity scheduling

- **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**
    - Connection 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

# 2010 MATSim configuration of long(er) term choices

- Social network geography
- Social commitments
- Occupation

  - Work location
  - School location
  - Home location

    - Mobility tools
    - Discount cards
    - Season tickets
    - Vehicles (by body type, fuel, energy efficiency)

# Challenges 2

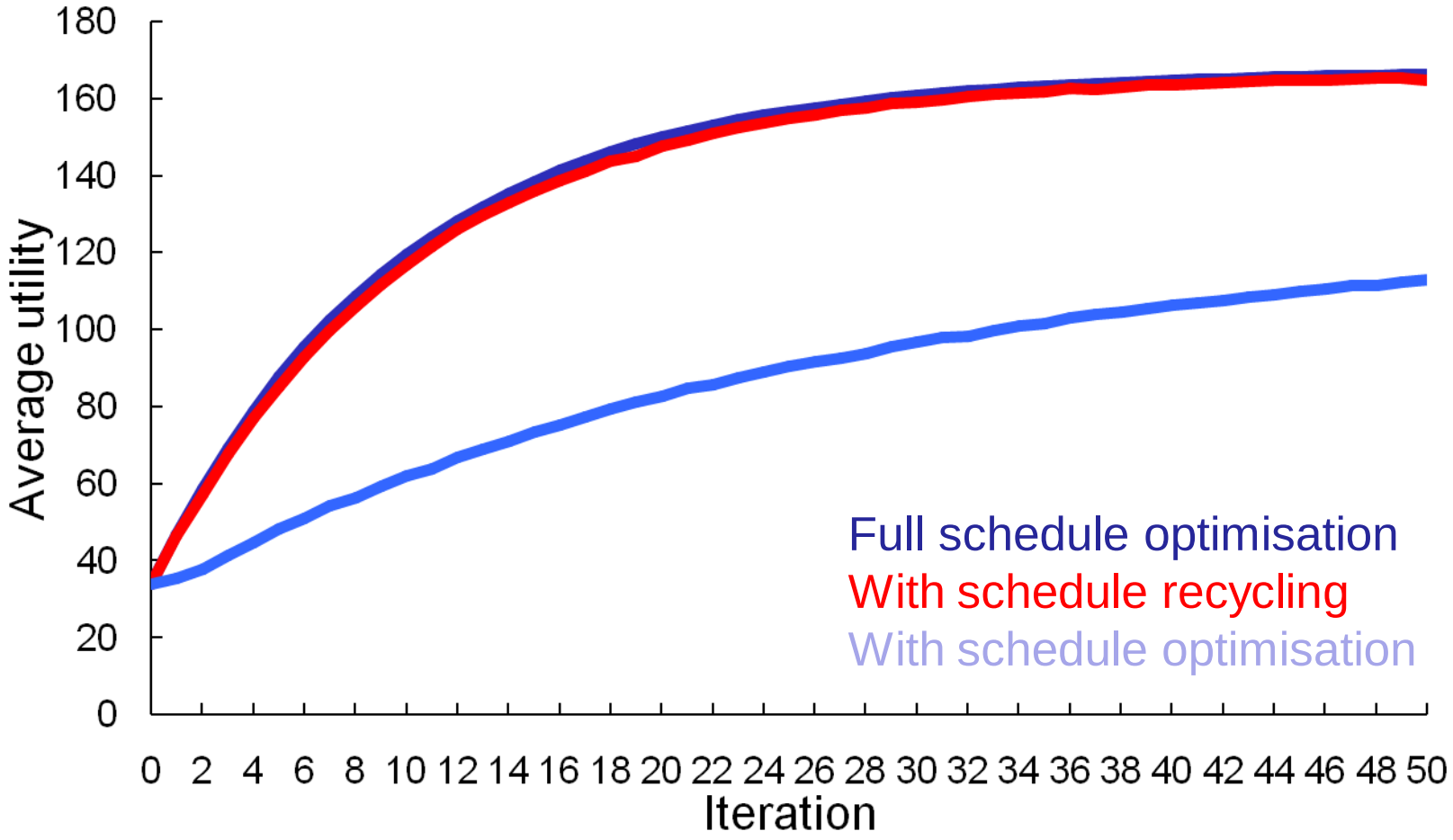
- Better initial schedules for iteration 0
- Regret-based identification of agents for replanning
- Reduce search spaces (extend time-space prisms)
- Recycle scheduling “solutions”
- Parallel traffic flow simulation
- [Warm start capabilities]

# Recycling strategy: Overall approach

- Optimise schedules (using a tabu-search approach) for a sample of agents
- Find the optimal metric to match further agents to optimised sample (maximum utility gain)
- Attach optimised schedules with optimally matched agents
- Adjust remaining degrees of freedom

Feil, Balmer and Axhausen, 2009

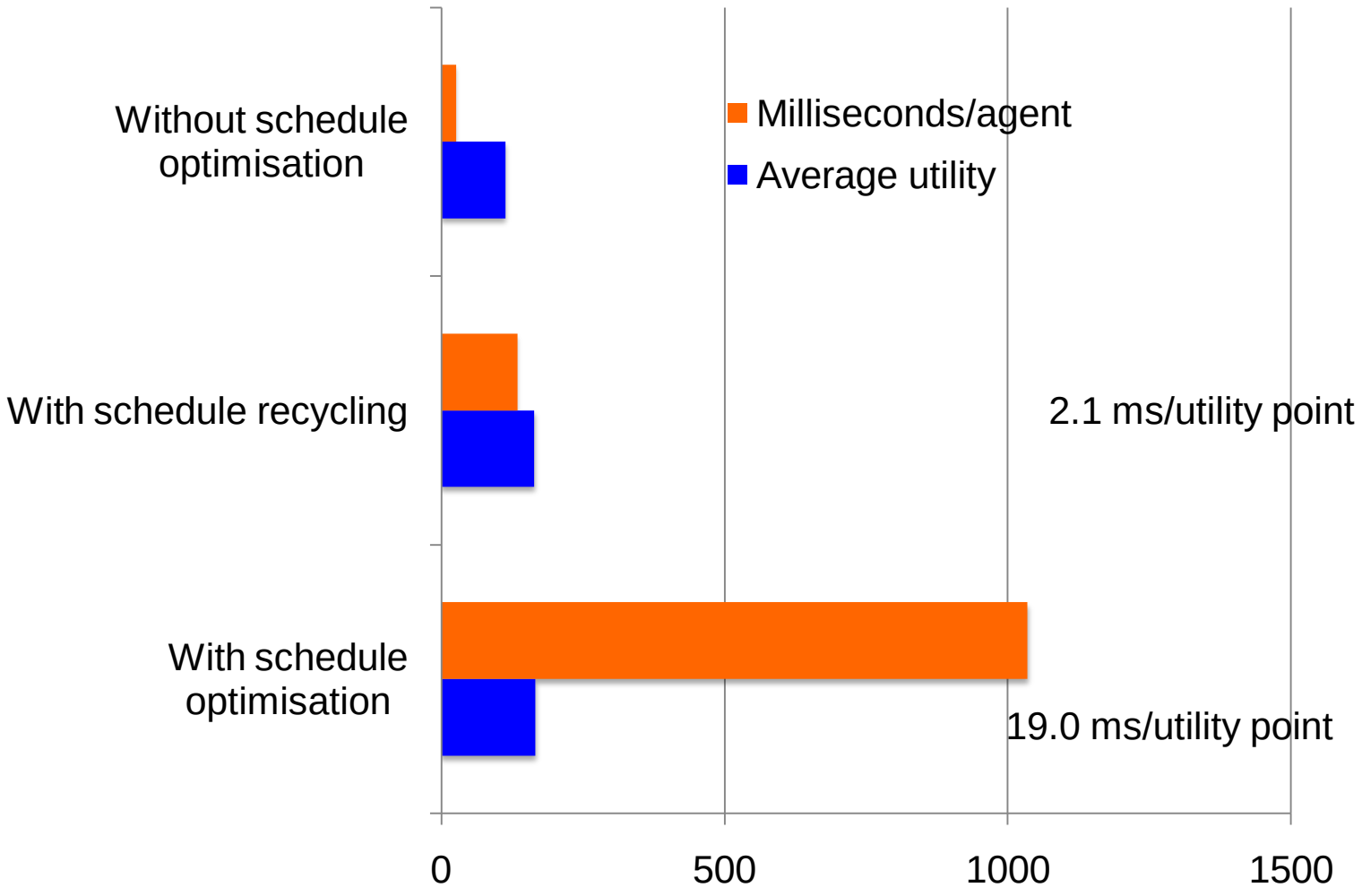
# Recycling strategy: Average utility




Diluted Zürich scenario;
170'000 agents;
navigation network for 35km around Zurich

Feil, Balmer and Axhausen, 2009

# Recycling strategy: Computational experience




Feil, Balmer and Axhausen, 2009

# Challenges 3

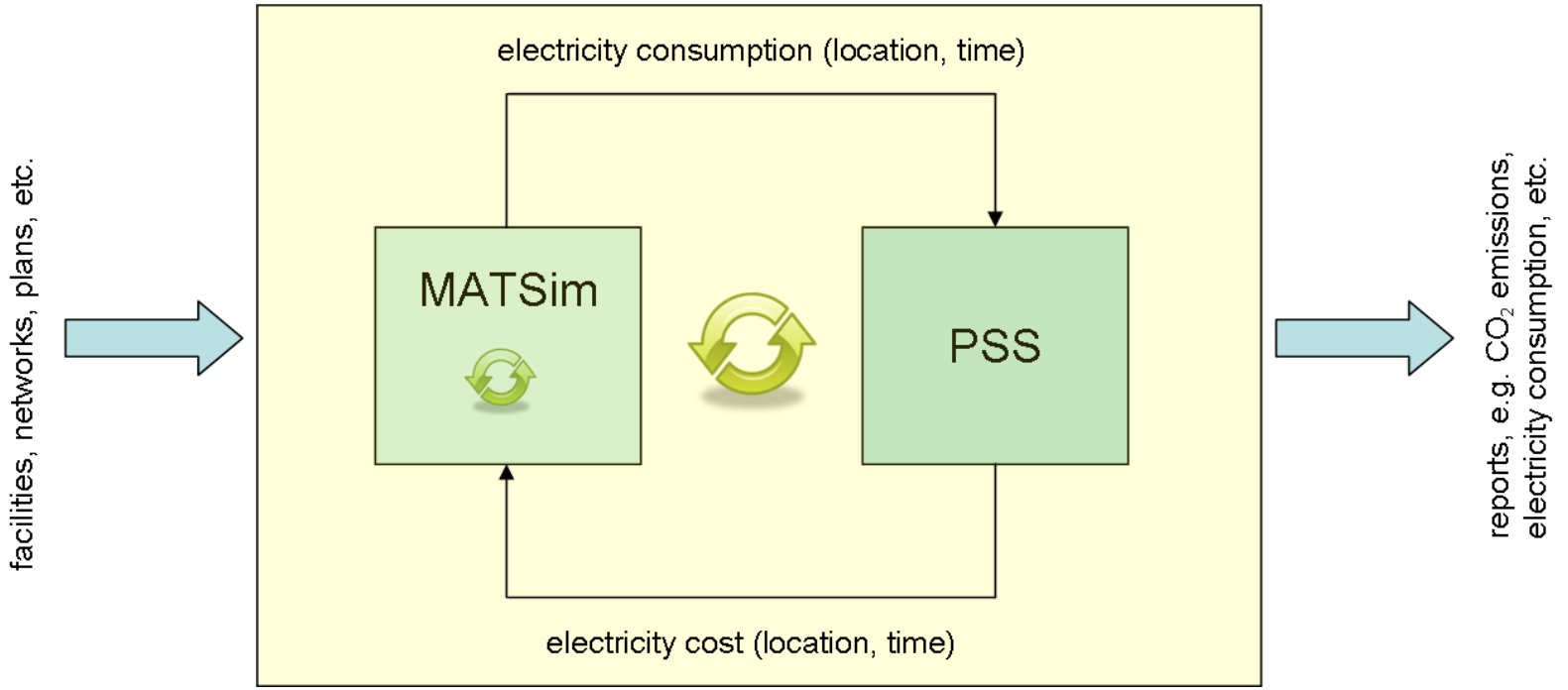
How to integrate the transport supply side ?

- Recharging infrastructure for EV (ETH)
- Placement of car sharing fleets (Dissertation Ciari)
- Necessary share of car pooling participants (ASTRA)
- Location, size and pricing of shared ride taxi fleets
- Pricing of parking
- Pricing of road use

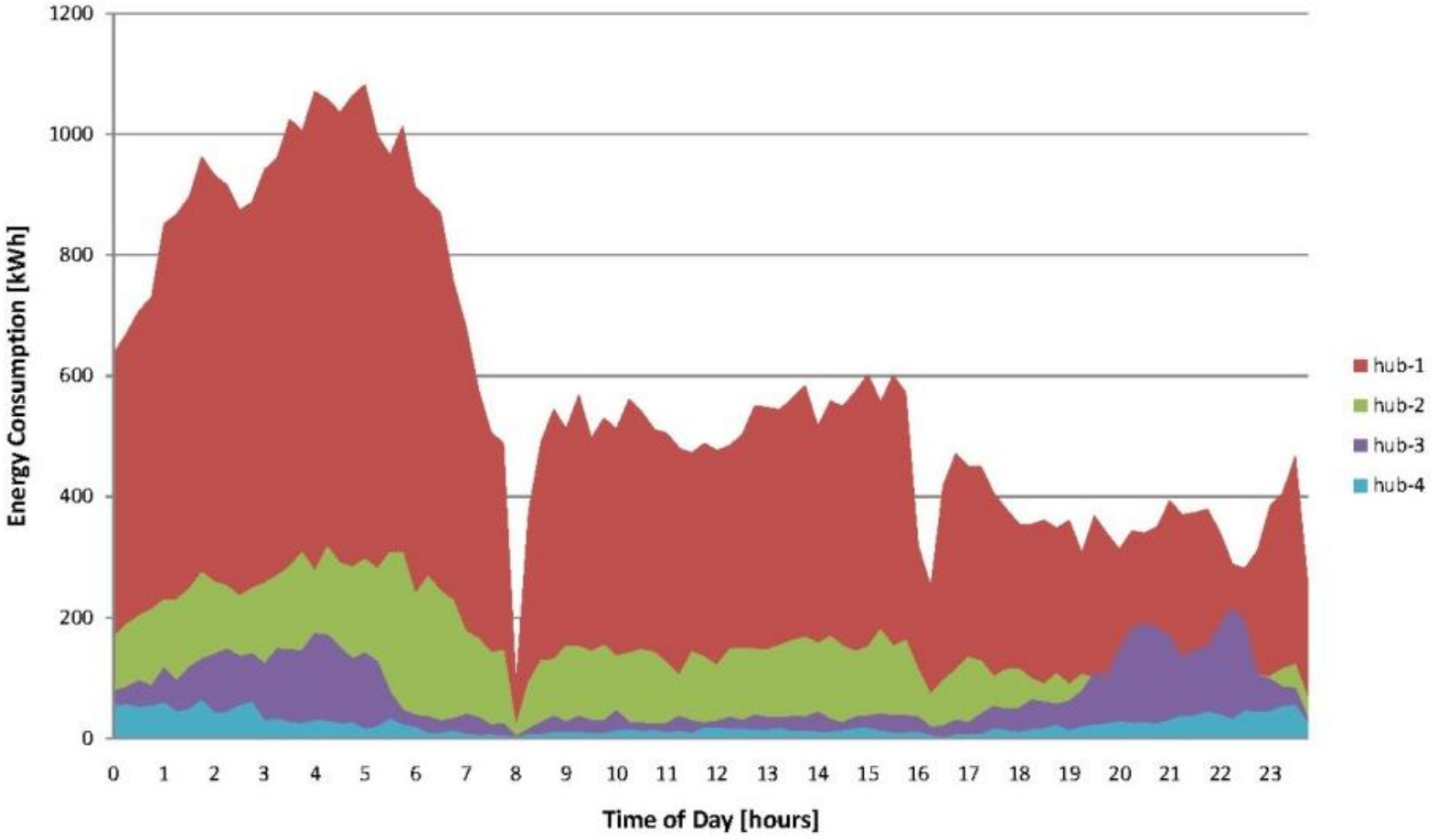
How to integrate facility supply ?

- Location of retailing facilities (ETH)
- Housing
- Network growth

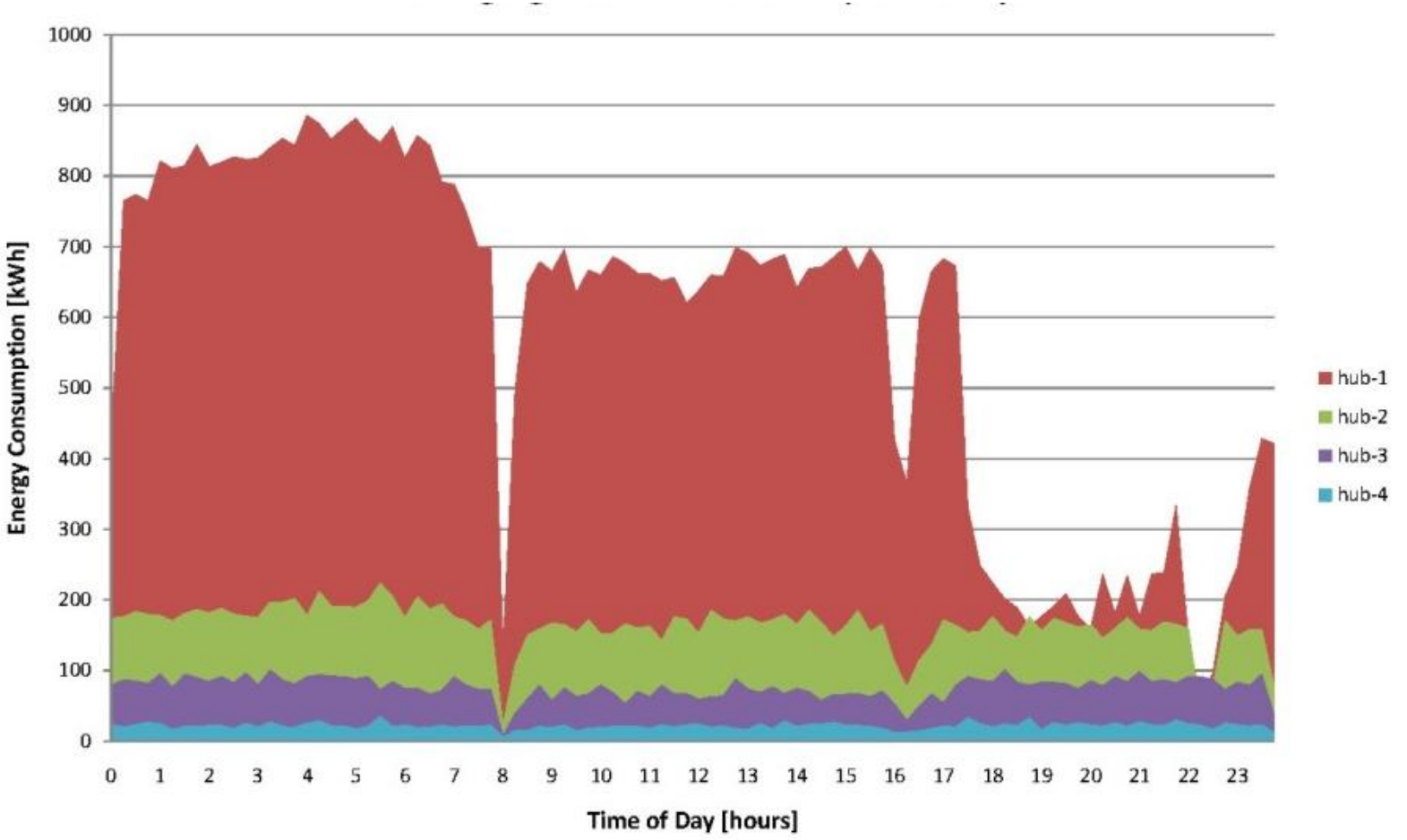
# Communication between MATSim and energy



# Before smart charging



# After smart charging



# Challenges 4

How to obtain the estimation data ?

- For the scheduling model
- For the model of induced demand
- For the supply side response

How to obtain validation data ?

- For the current situation
- For policy experiments

# An MNL model of activity scheduling – overview

Utility function:

- Joh's S-curve

Estimation data:

- MZ 2005 (Zürich subsample)

- Time-of-day specific travel times from MATSim
- Joh's measure of similarity was tested

Set of non-chosen alternatives:

- Tabu-search interim results

# An MNL model of activity scheduling: Formulation

## Activities

$$U_{activities} = (1 + \beta_{female\_act} \cdot Female) \cdot \sum_i \left[ \frac{U_i^{max}}{(1 + \gamma_i \cdot exp\left[\beta_i(\alpha_i - t_{perf,i})\right])^{1/\gamma_i}} \right]$$

i: activity i

$\gamma_i = 1$ for all activities i

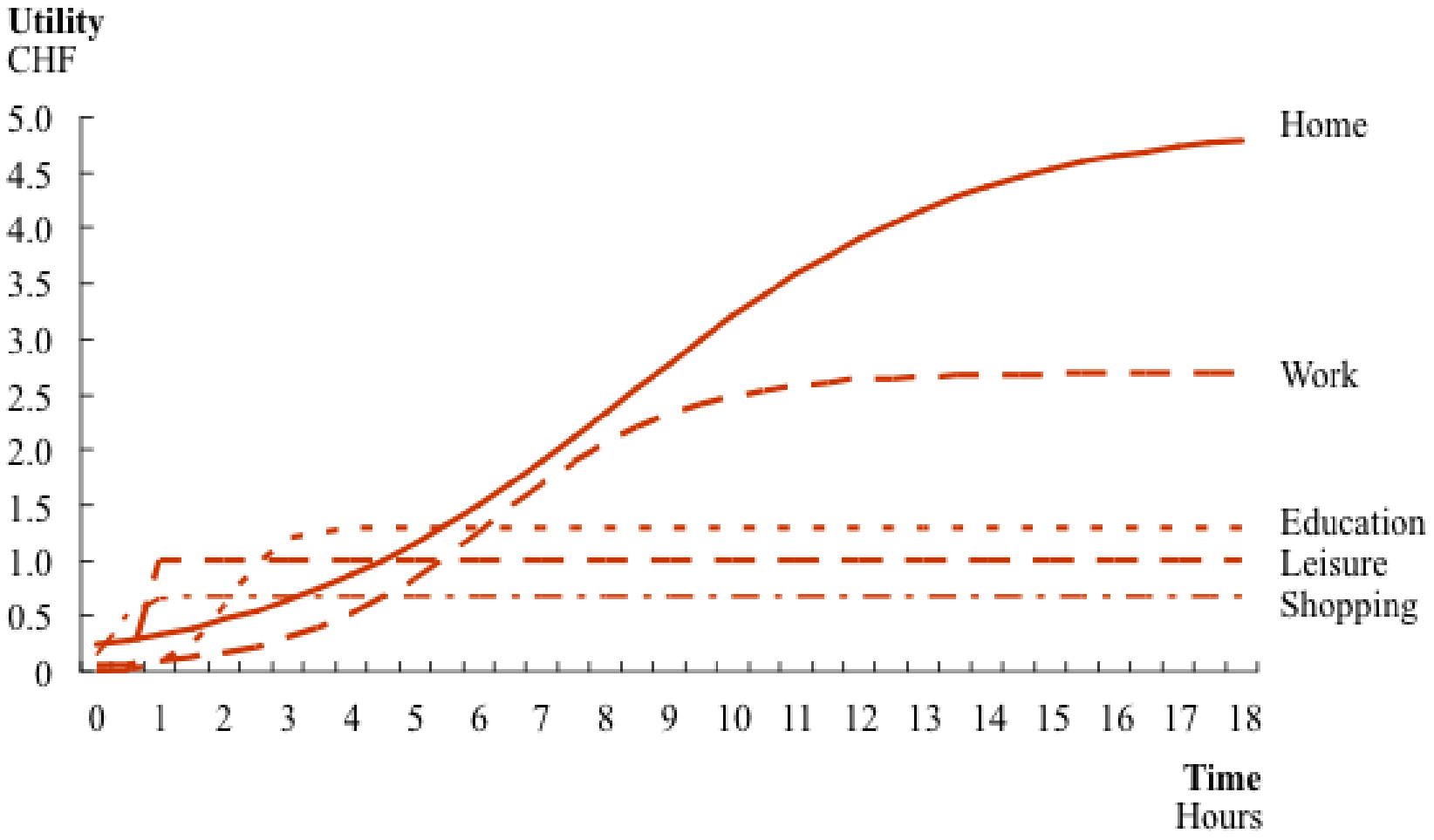
## Travel

$$U_{travel} = (1 + \beta_{female\_travel} \cdot Female) \cdot \sum_j \left[\beta_{time\_j} \cdot time_j\right] + \\ + \sum_j \left[\beta_{cost\_j} \cdot cost_j + constant_j\right]$$

j: travel leg j

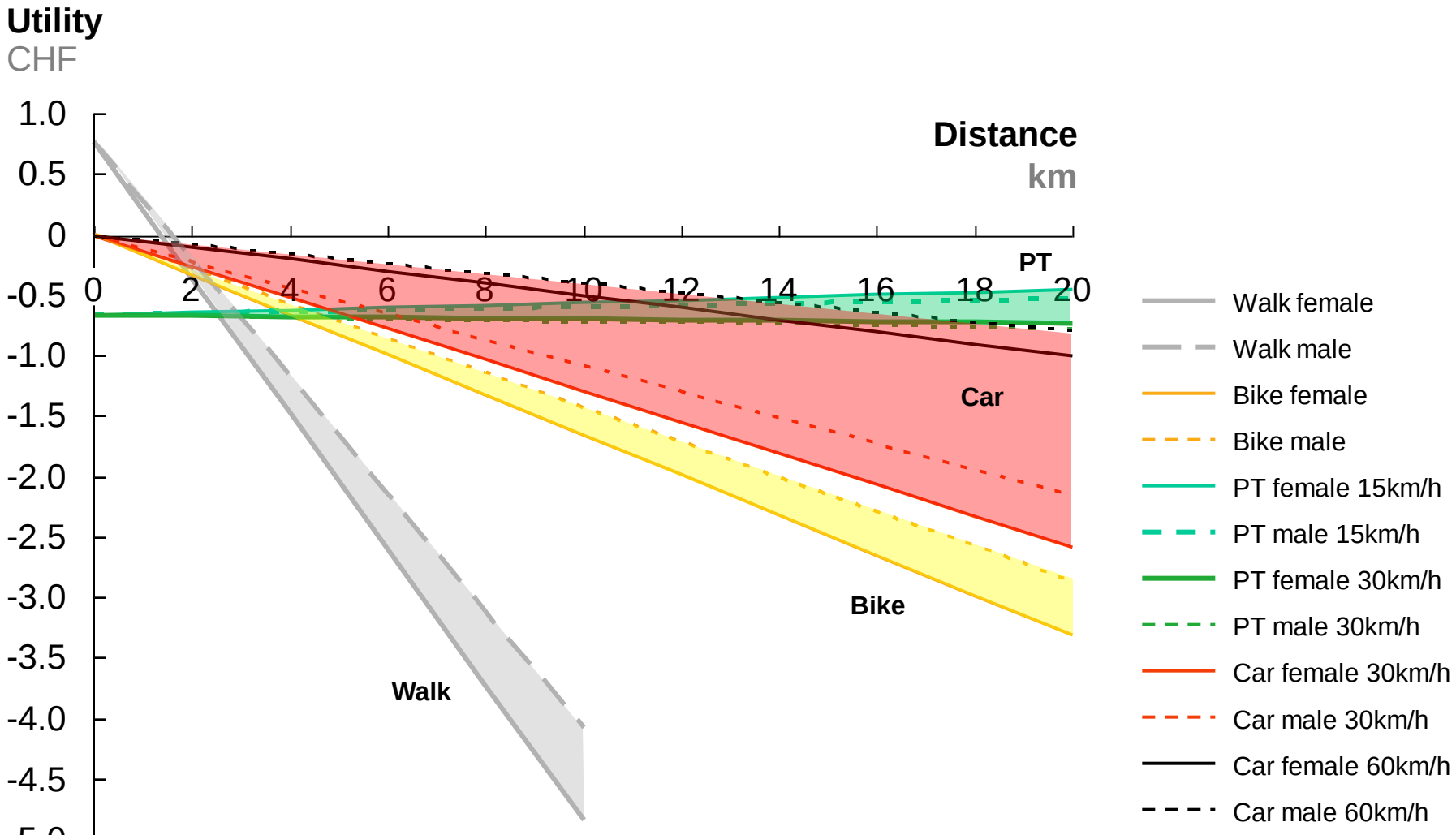
Feil, Balmer and Axhausen, 2009

# An MNL model of activity scheduling: First results




Feil, Balmer and Axhausen, 2009

# An MNL model of activity scheduling: First results




Feil, Balmer and Axhausen, 2009

# Challenges 5

What is faster ?

- (Random) choice set generation and “choosing”
- (Incrementally) optimised schedules for heterogenous users
- Rule-based scheduling systems

Where is the optimal point ?

- Number of iterations (search space coverage) versus
- smart share of agents to replan

# Challenges 6

How to integrate social networks ?

- Construct the networks
- Updating rules in a comparative static model
- Validation of network structures

How to integrate with path-oriented land use models ?

- Reduction of computation times
- Non-equilibrium updating

# www.matsim.org@ ETH Zürich

- Michael Balmer
- David Charypar
- Francesco Ciari
- ChristophDobler
- Matthias Feil
- Jeremy K. Hackney
- Andreas Horni
- Konrad Meister
- Nicolas Lefebvre
- Rashid Waraich