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Switzerland in a box: An agent-based model of travel demand and traffic flow

KW Axhausen and M Balmer

June 2008

Institut für Verkehrsplanung und Transportsysteme
Institute for Transport Planning and Systems

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Agent-based simulation of travel demand: Structure and computational performance of MATSim-T

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Structure

Software:

- Open-source project under GNU public licence

Coordination:

- Kai Nagel, TU Berlin

Data:

- Public sources, where available
- Private sources, when needed or as occasion arises

Current team

Strategy:

- Kai Nagel, TU Berlin

- Kay Axhausen, ETH Zürich
- Fabrice Marchal, LET, Lyon

Coordination of the implementation and project management:

- Michael Balmer, ETH Zürich

    - Marcel Rieser, TU Berlin

Current team: Implementation (1/2)

- Michael Balmer, ETH
- David Charypar, ETH
- Yu Chen, TU Berlin
- Francesco Ciari, ETH
- Dominik Grether, TU Berlin
- Jeremy Hackney, ETH
- Andreas Horni, ETH
- Johannes Illenberger, TU Berlin
- Gregor Lämmel, TU Berlin
- Michael Löchl, ETH

Current team: Implementation (2/2)

- Fabrice Marchal, LET
- Konrad Meister, ETH
- Kai Nagel, TU Berlin
- Andreas Neumann, TU Berlin
- Marcel Rieser, TU Berlin
- Nadine Schüssler, ETH
- David Strippgen, TU Berlin
- Rashid Waraish, ETH

Task and solution methods

Understanding scheduling

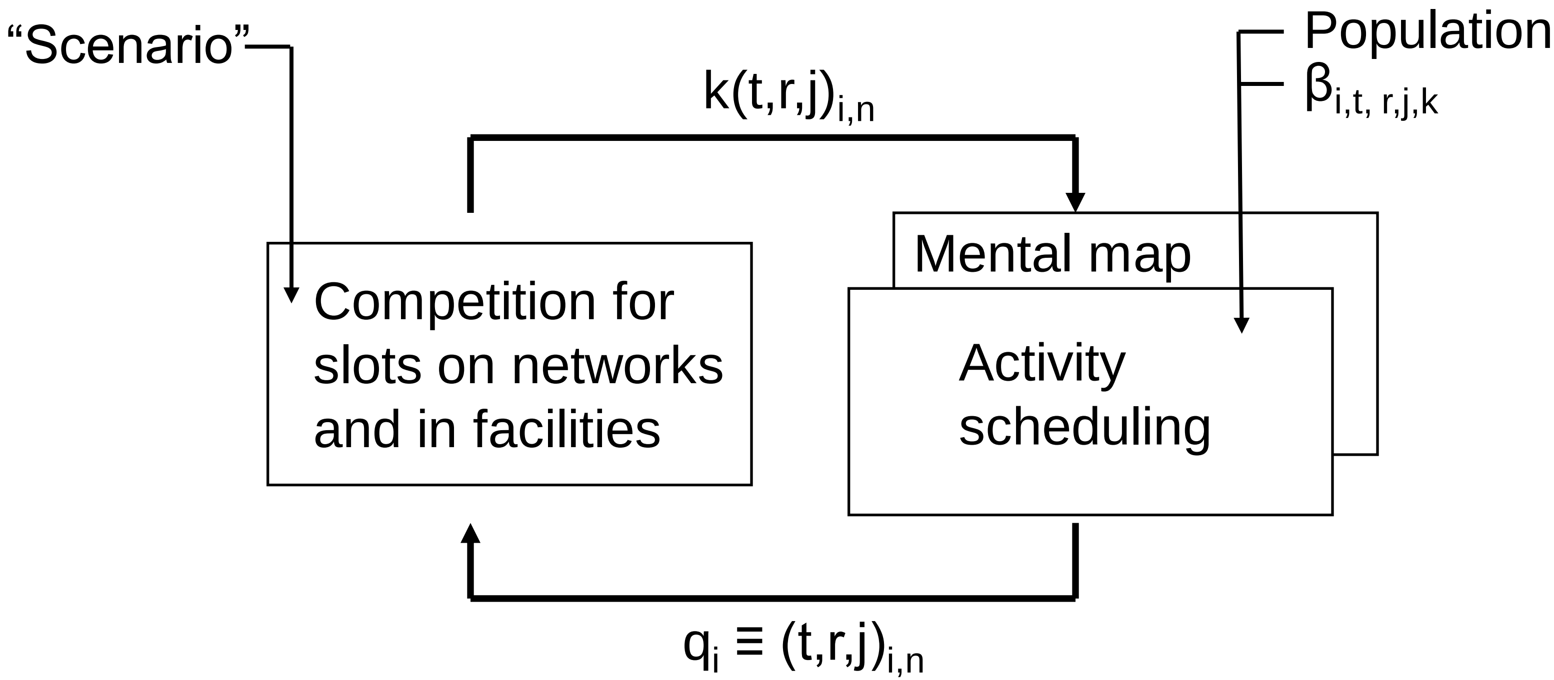
- Budget constraints
- Capability constraints

- Generalised costs of the schedule

  - Generalised cost of travel
  - Generalised cost of activity participation

    - Risk and comfort-adjusted weighted sums of time, expenditure and social content

What does MATSim-T do ?



Demand q are the i^{th} movements of person p from the current location at time t on route (connection) r to location j. The resulting generalised costs k are used to adjust the schedules and to change the capacities C and prices P of facilities f

Classification criteria

- Steady state (equilibrium) ?
- Aggregate demands ?
- Complete and perfect knowledge ?
- Optimised schedules ?
- Degrees of freedom and detail of scheduling
- Modelling of capacity restrictions (movement, activities) ?

MATSIM-T: Steady-state version

- Scale: 7.5 mio agents, 1 mio facilities, 1 mio links and nodes
- Continuous time resolution;
- spatial resolution: individual facilities;

- Shared time-of-day dependent generalised costs of travel and activity participation
- Best-response models for schedules and routes
- (Random) imputation of mode and location

- Queuing for slots for movement (and activities)

Preferred configuration: Initial demand generation

- *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
      - *Vehicle/means of transport*
      - Route/service
      - Group travelling together
      - Expenditure division

Preferred configuration: (Iterative) 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
            - Vehicle/means of transport
            - Route/service
            - Group travelling together
            - Expenditure division

Preferred configuration: Competition for slots

Movement:

- Queue-based simulation of car traffic
- (Traffic signal can be explicitly represented)
- No cycling, walking, public transport networks or timetables yet

Activities

- No competition for facilities yet
- Type- and location-specific opening hours
- Capacities are known

Result of each iteration: Plan


```xml
<person id="22018">
    <plan score="157.72" selected="yes">
        <act type="h" x="703600" y="236900" link="5757"
                                                end_time="07:35:04" />
        <leg num="0" mode="car" dep_time="07:35:04" trav_time="00:16:31">
                <route>1900 1899 1897</route>
        </leg>
        <act type="w" x="702500" y="236400" link="5749" dur="08:12:05" />
        <leg num="1" mode="car" dep_time="16:03:40" trav_time="01:10:22">
                <route>1899 1848 1925 1924 1923 1922 1068</route>
        </leg>
        <act type="l" x="681450" y="246550" link="2140" dur="01:20:00" />
        <leg num="2" mode="car" dep_time="" trav_time="00:34:35">
                <route>1067 1136 1137 1921 1922 1923 1925 1848 1899</route>
        </leg>
        <act type="h" x="703600" y="236900" link="5757" />
    </plan>
</person>
```

Iterative learning and its (schedule) utility function

Utility function: Individual schedules

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

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

Example scenario

Why MATSim-T scales (roughly) linearly ?

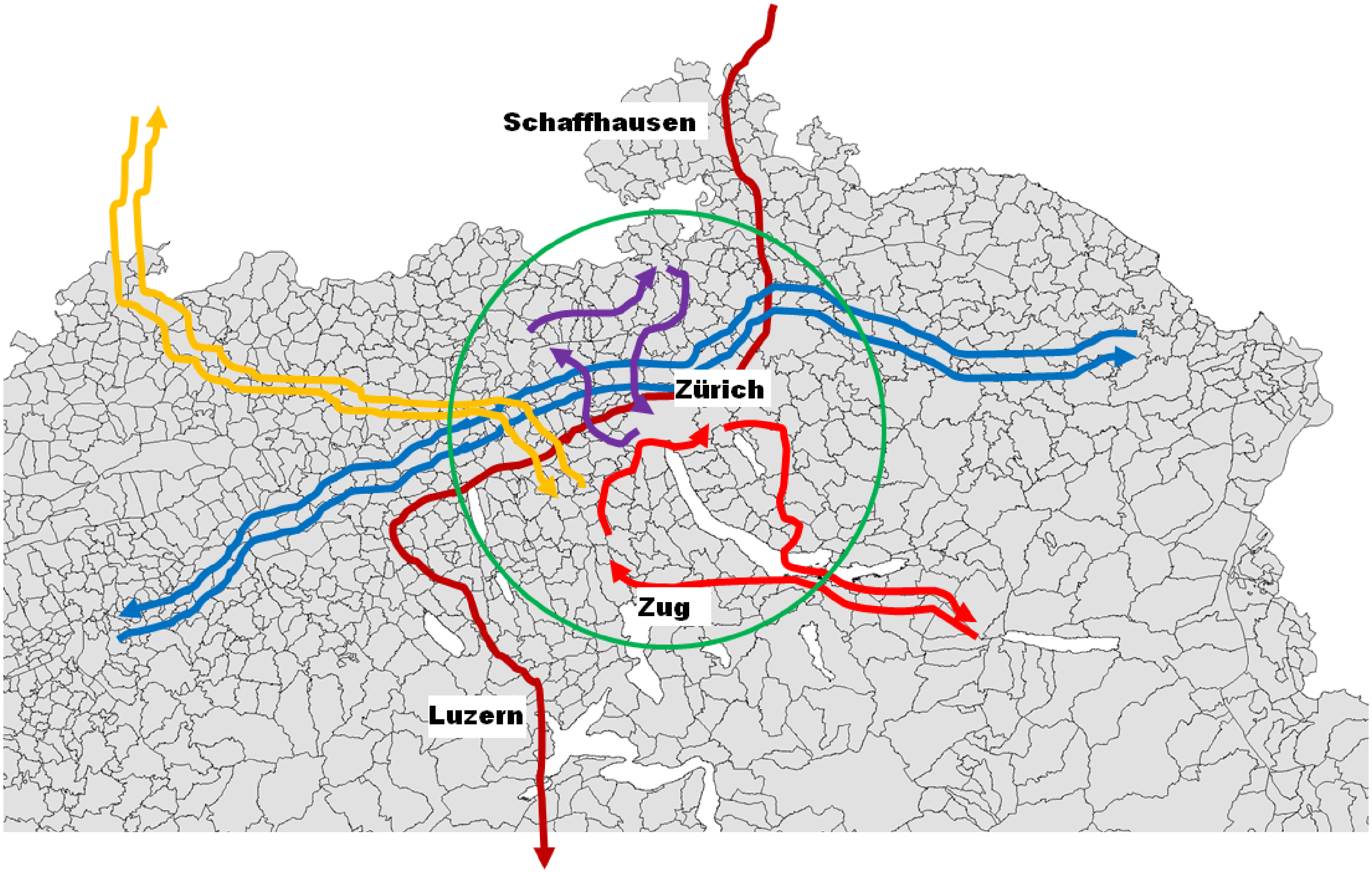
- Initial demand ~ N_{agents}
  - Location choice ~ N_{agents} * [$N_{facilities}$ or R_{prism}^{β}]
  - Mode choice ~ N_{agents} * N_{modes}

- Optimising times and durations ~ $N_{activities}^{\alpha}$
- Shortest paths ~ N_{nodes}^{γ}

- Event-oriented traffic flow ~ N_{agents} * $N_{links\ in\ a\ route}$
- Time-step traffic flow (1sec) ~ N_{links}

In principle, scale all processes by $1/N_{CPU}$

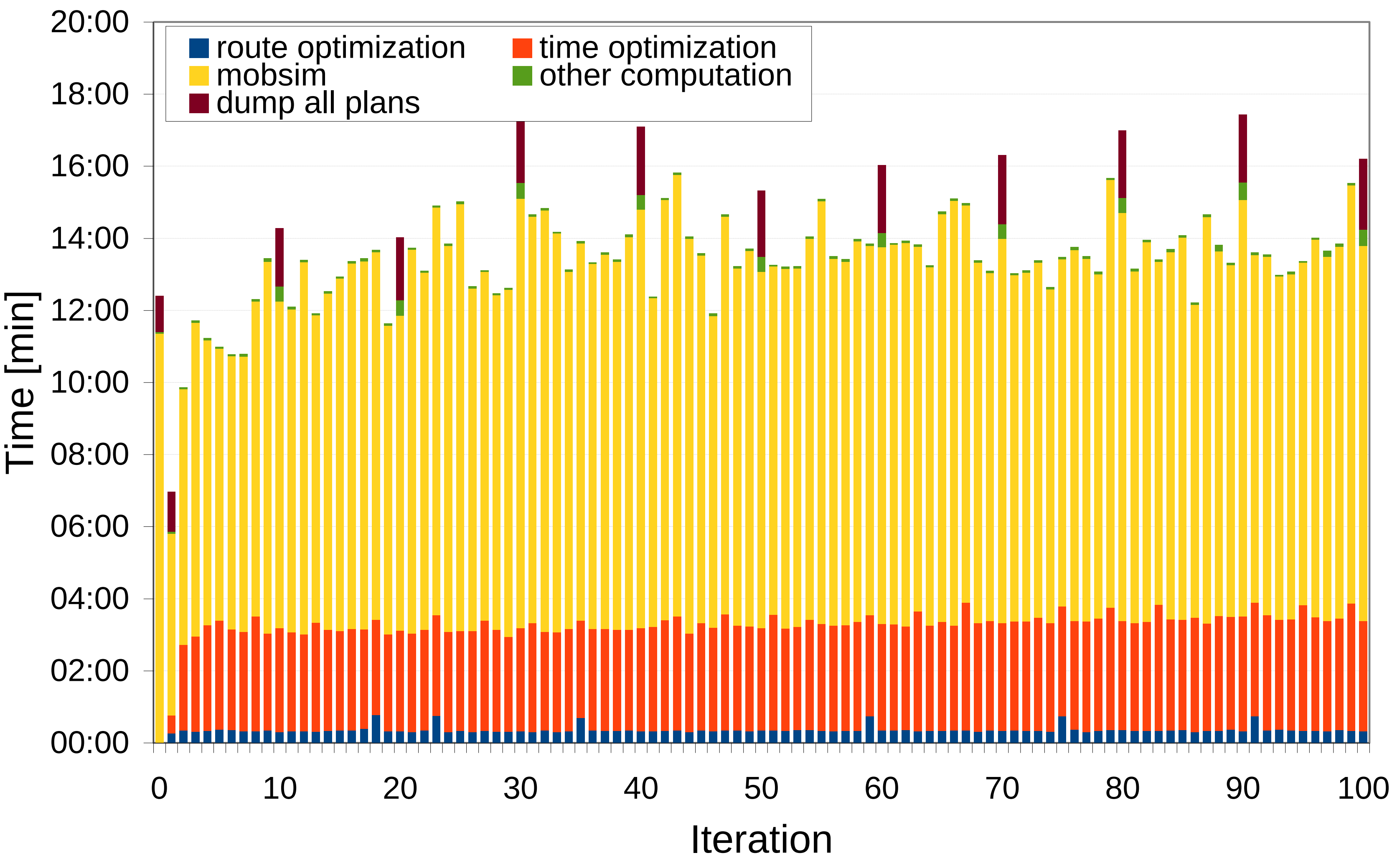
Example scenario: Study area and population



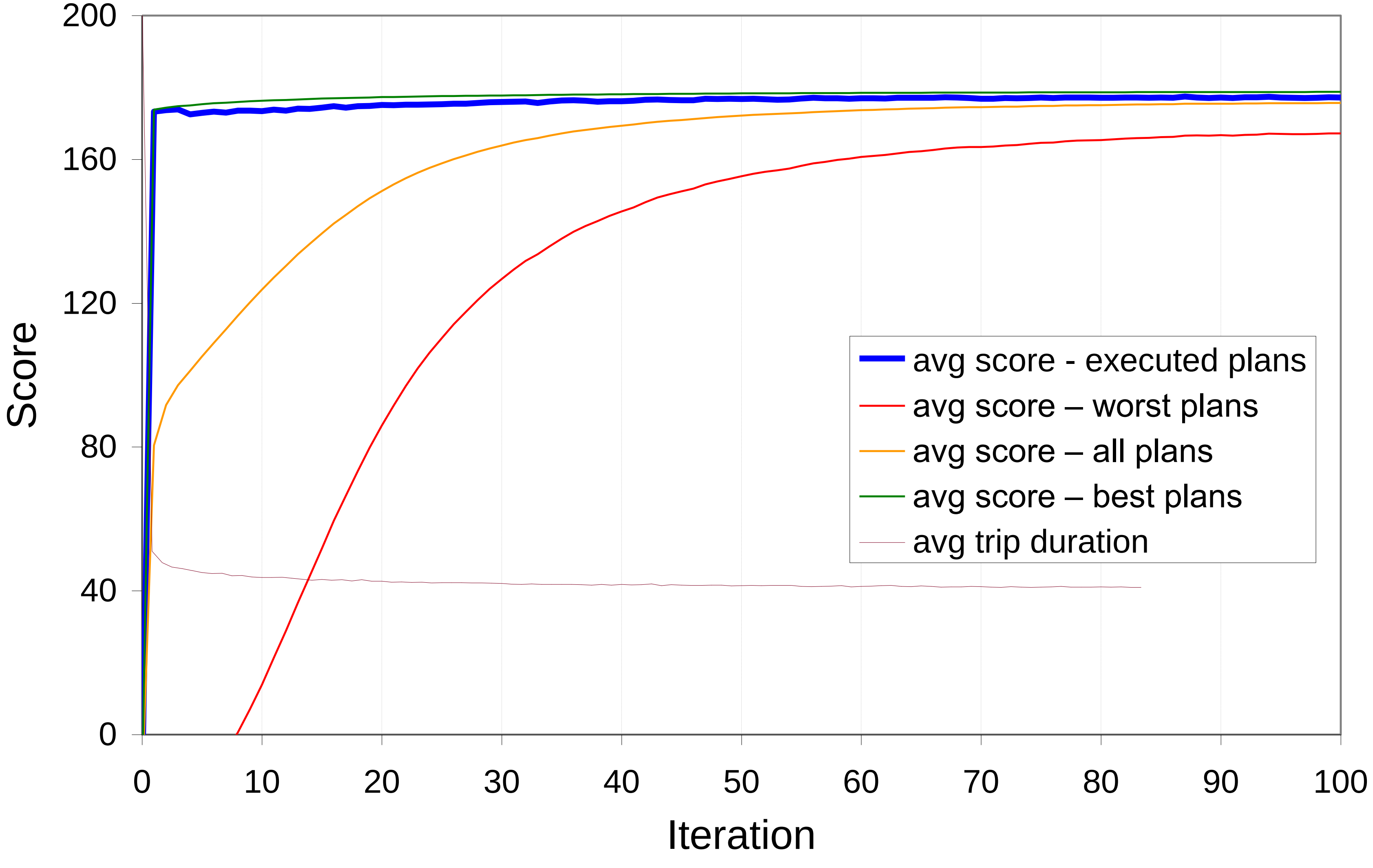
Example scenario: Problem size of the 10% sample

Directed links	60’492
Nodes	24’180
Agents within the study area	181’693
Average number of trips/agent	3.1
Trips (agents) crossing the study area	5’791
Number of modes/activity types	5/17
Number of homes (facilities)	1'313'337
Number of out-of-home activity facilities	382'979
Number of additional facilities abroad	880

Computing times by step



Score by iteration

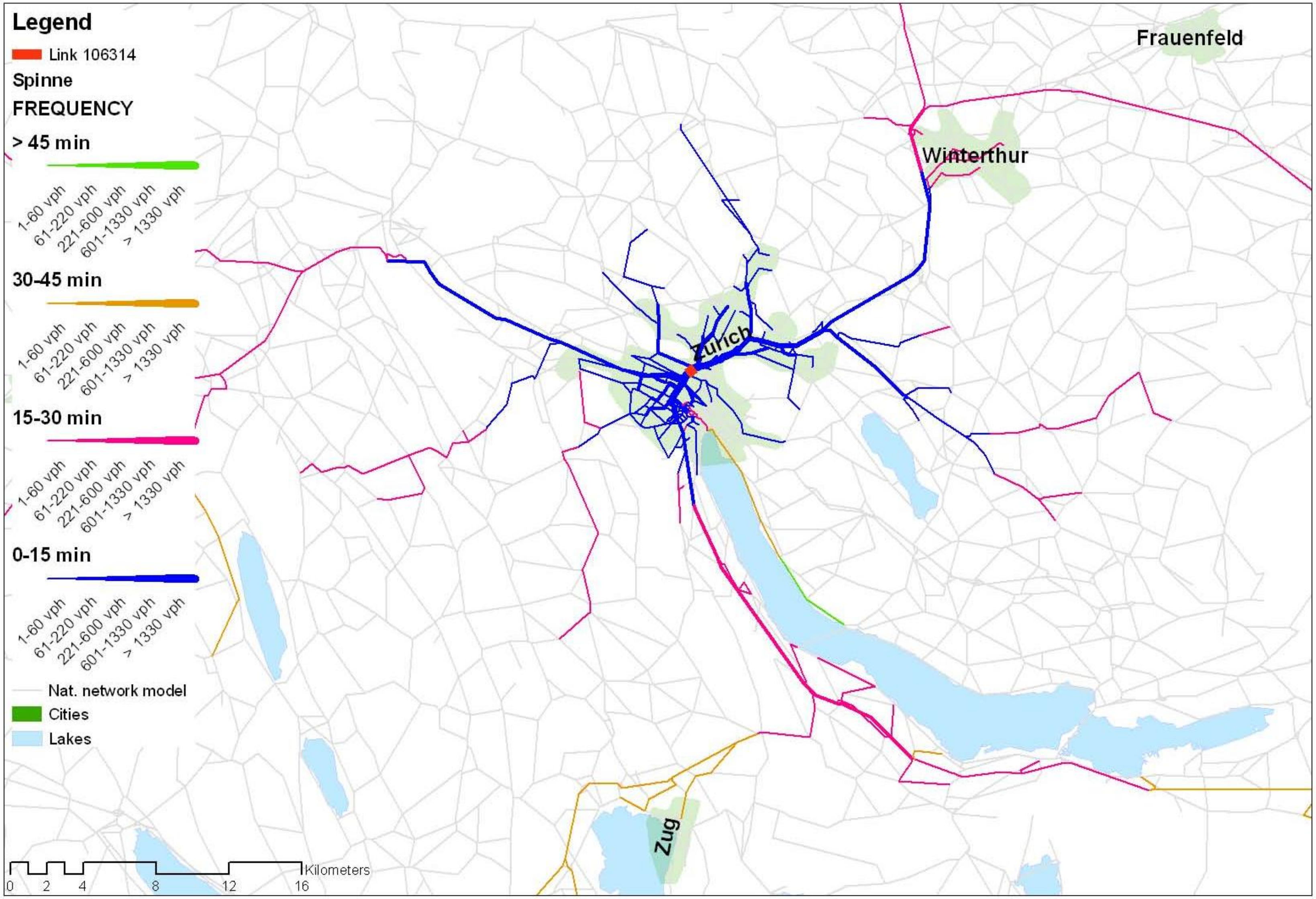


Computing times by step

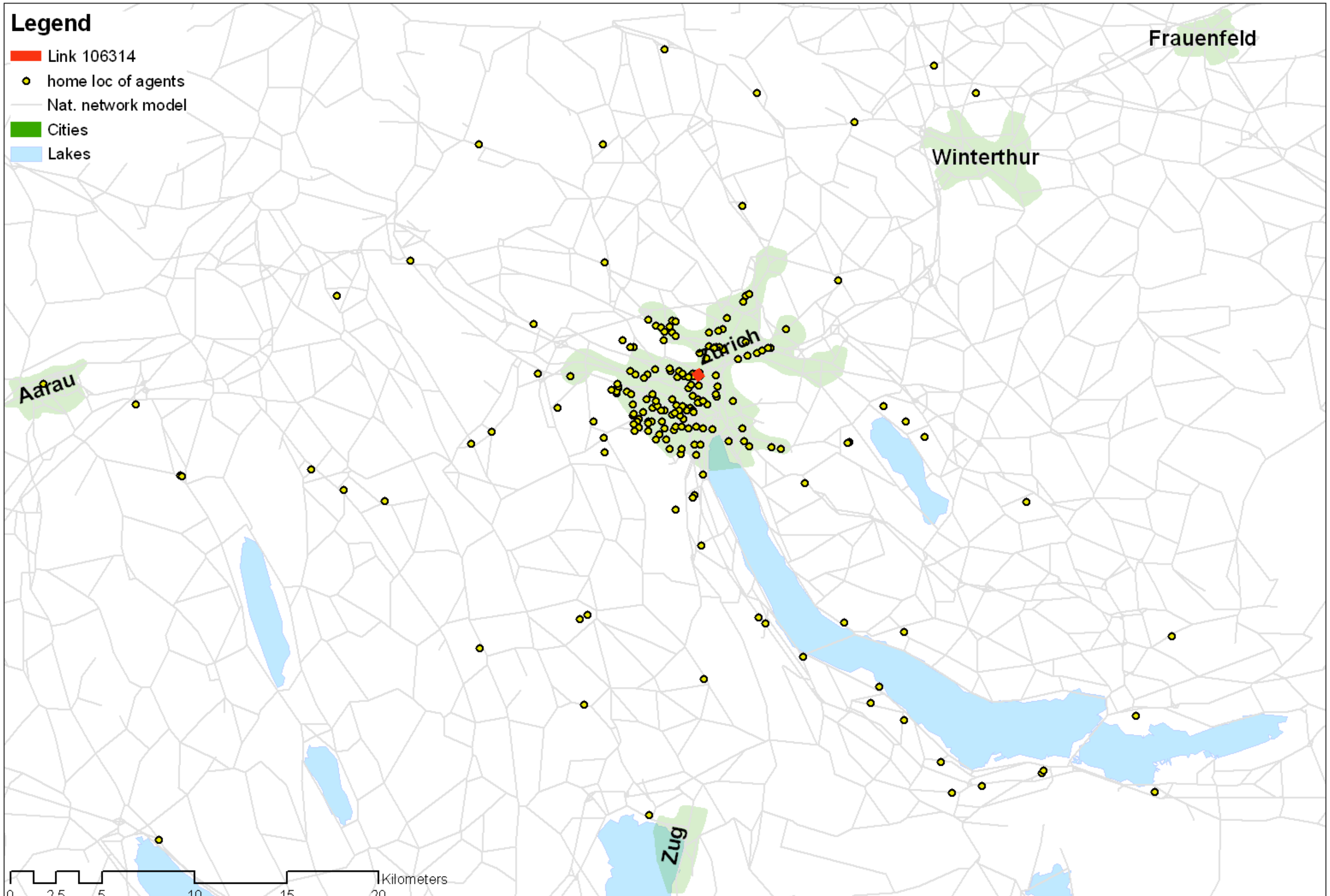
Operation	Unit	Units/sec
Initial demand		0.12h
Scheduling (fixed components)		14.40h
Scheduling (planomat)	Agent	100
Scheduling (routing)	Agent	1000
Time-step based traffic flow simulation	Agent	300
Learning	Agent	250’000
Total iteration (with I/O)		0.22h
Total run (with I/O) (100 iterations)		23h

Validation

Agents flowing to and from a link arriving at 16-17:00



Home locations of the agents using a link from 16-17:00



Outlook

Current tasks: Functionality

- Improving the realism of the scenario (e.g. parameter distributions)
- Parameter estimation for the utility function

- Switzerland scenario in 12h to steady state

- Functional expansion the planomat (mode choice, destination choice – sequencing of activities)

- Multi-modal traffic flow simulation

Future tasks: Functionality

- Integration of social network data structures
- Explicit social network-based choices

- Interface to UrbanSim *et al.*

- Addition of supply agents (car sharing, demand responsive transport, retail location, parking pricing, road pricing) (Traffic control)

More information

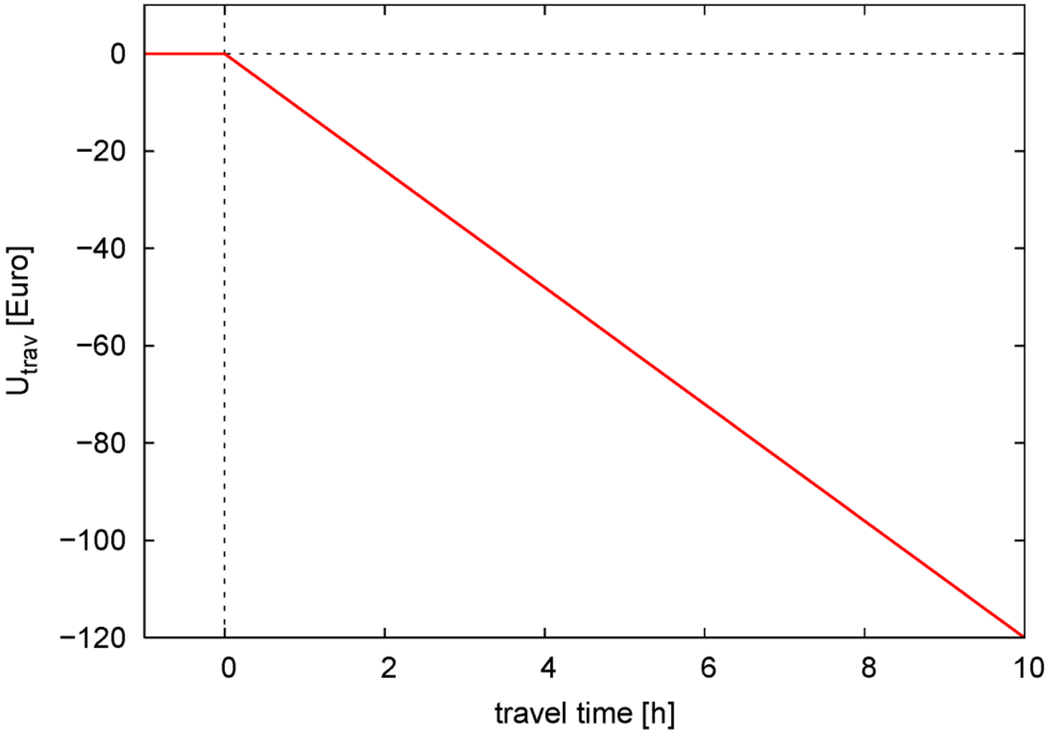
www.matsim.org

www.vsp.tu-berlin.de

www.ivt.ethz.ch/vpl/publications/reports

Appendix

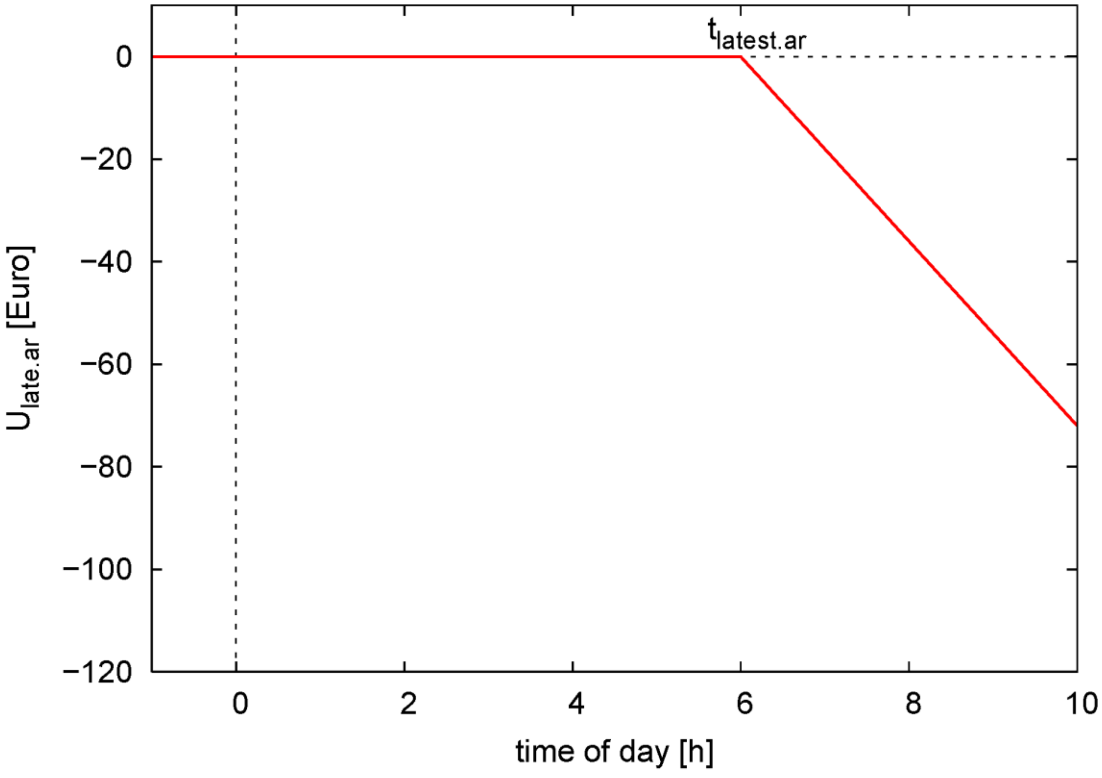
Utility function: Travel



$\beta_{trav} = -12\ Euro / h$

$$U_{trav,i-1,i} = \begin{cases} \beta_{trav} \cdot t_{trav,i-1,i} & if\ \ t_{trav,i-1,i} \geq 0 \\ 0 & else \end{cases}$$

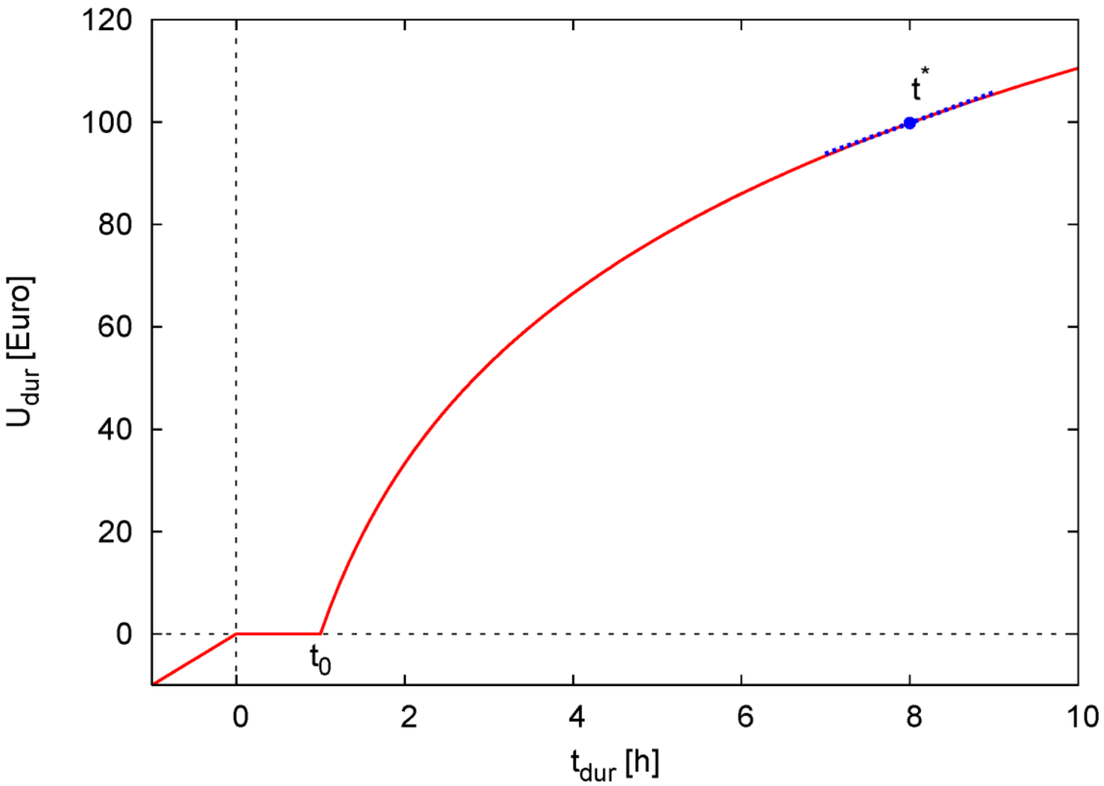
Utility function: Late arrival



$$\beta_{late.ar} = -18\ Euro/h$$

$$U_{late.ar,i} = \begin{cases} \beta_{late.ar} \cdot \left(t_{start,i} - t_{latest.ar,i}\right) & if\ \ t_{start,i} \geq t_{latest.ar,i} \\ 0 & else \end{cases}$$

Utility function: Activity performance

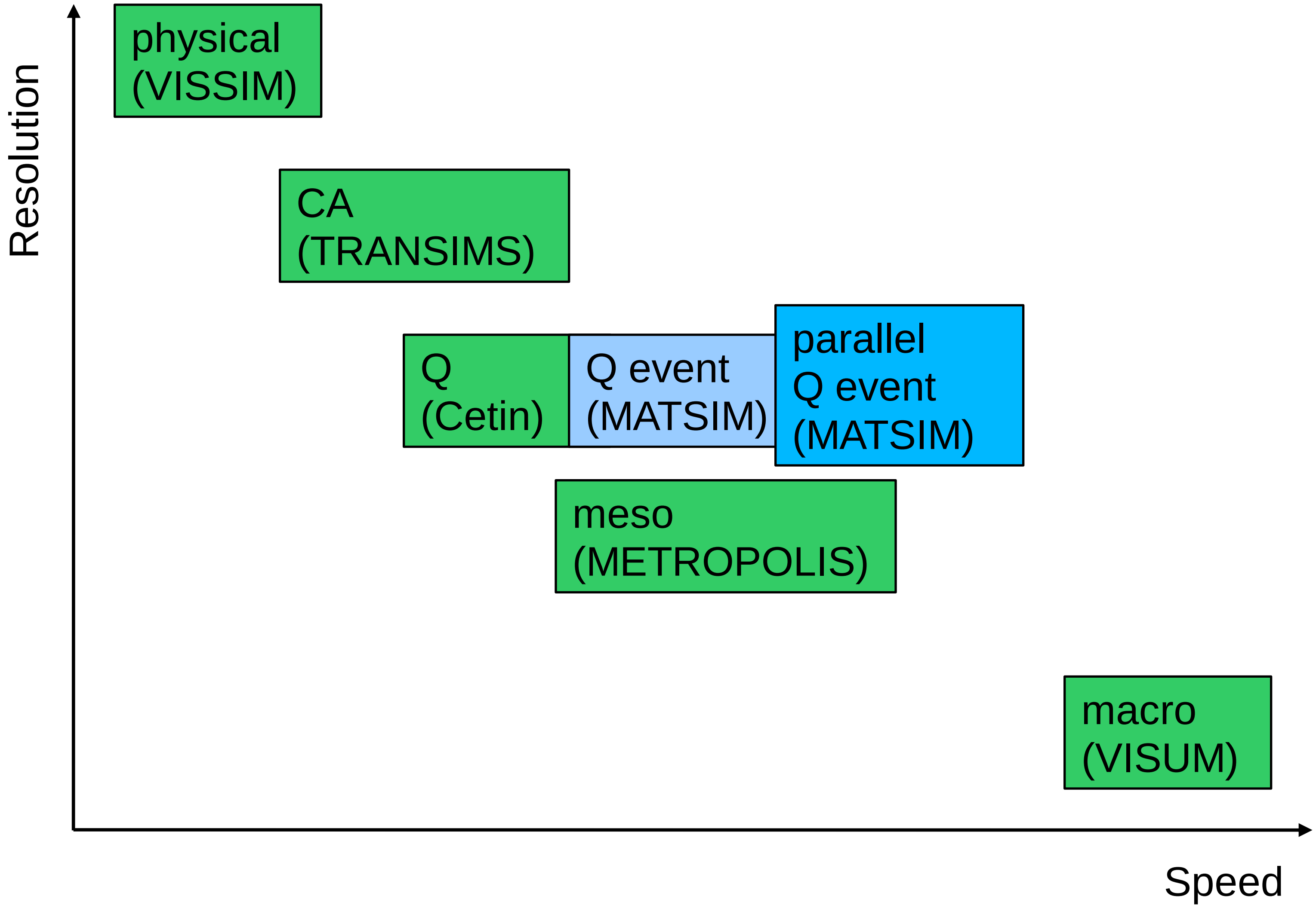


$$\alpha = 10 \; Euro/h$$

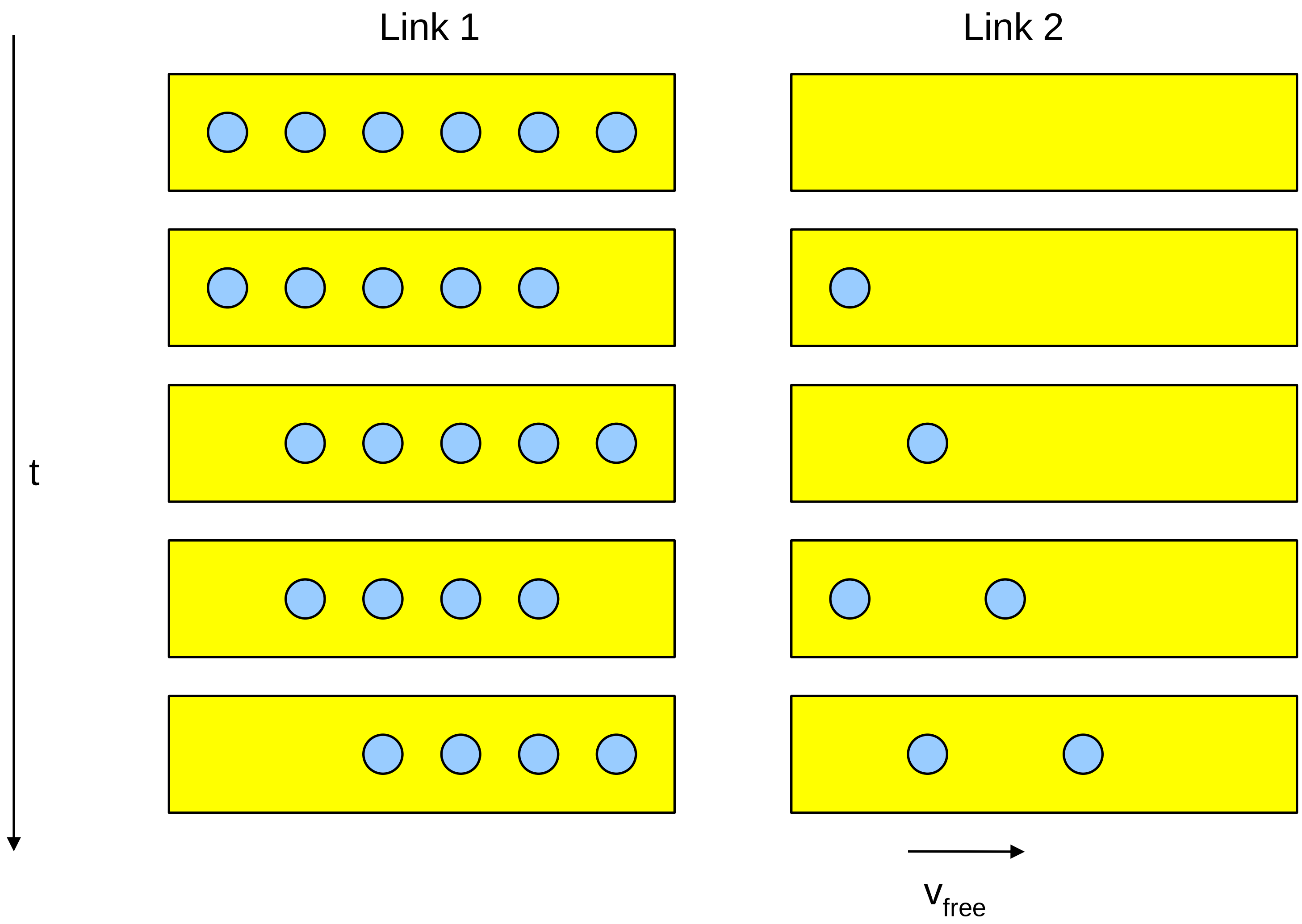
$$\beta_{dur} = 6 \; Euro/h$$

$$U_{dur,i} = \begin{cases} \beta_{dur} \cdot t^* \cdot \ln\left(t_{dur,i}/t_{0,i}\right) & if \;\; t_{0,i} \leq t_{dur,i} \\ 0 & if \;\; 0 \leq t_{dur,i} < t_{0,i} \\ \alpha \cdot t_{dur,i} & else \; (\alpha > 0) \end{cases}$$

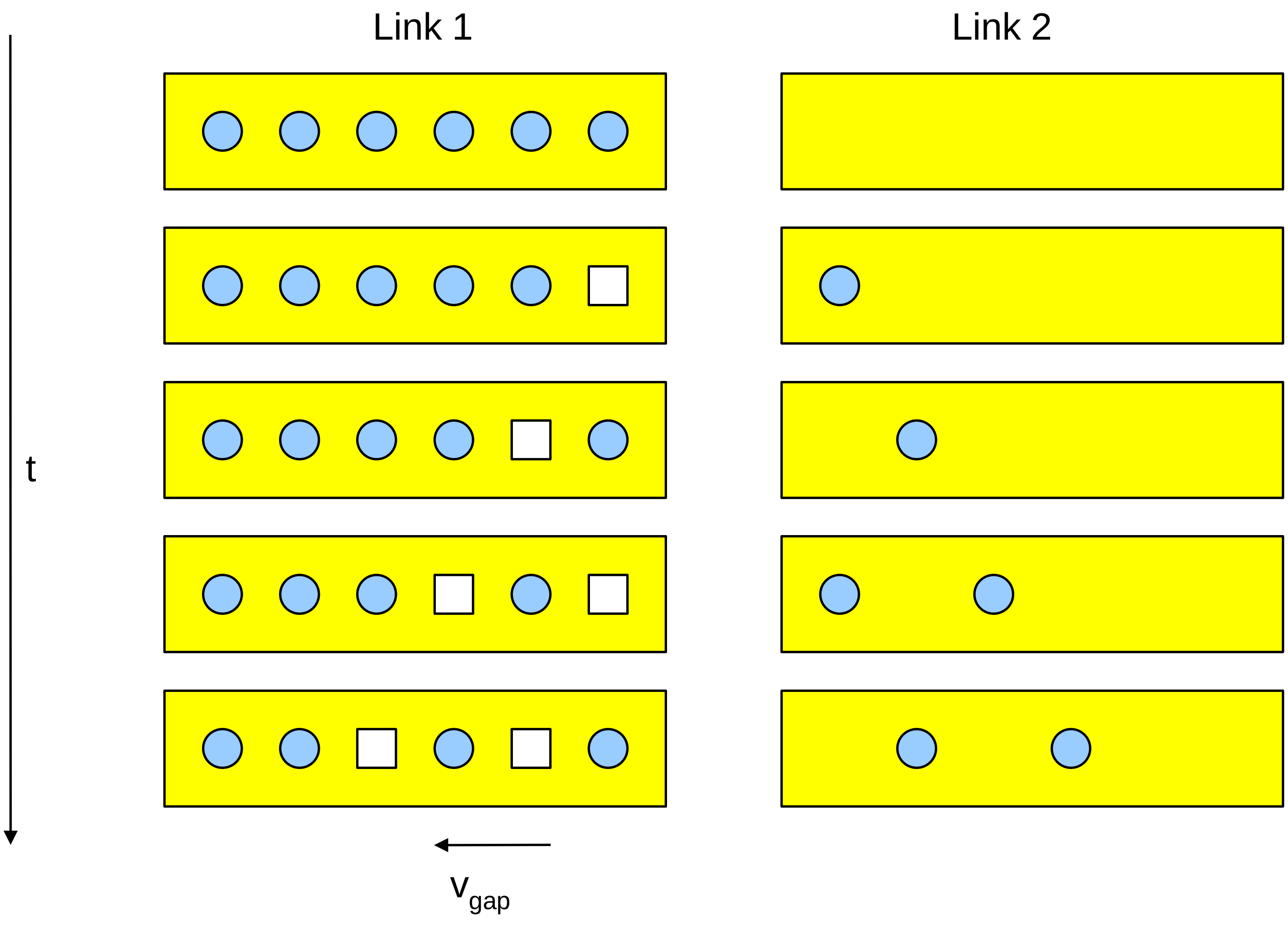
Approach


Resolution
physical (VISSIM)
CA (TRANSIMS)
Q (Cetin)
Q event (MATSIM)
parallel Q event (MATSIM)
meso (METROPOLIS)
macro (VISUM)
Speed

Q-event: Approach without gaps



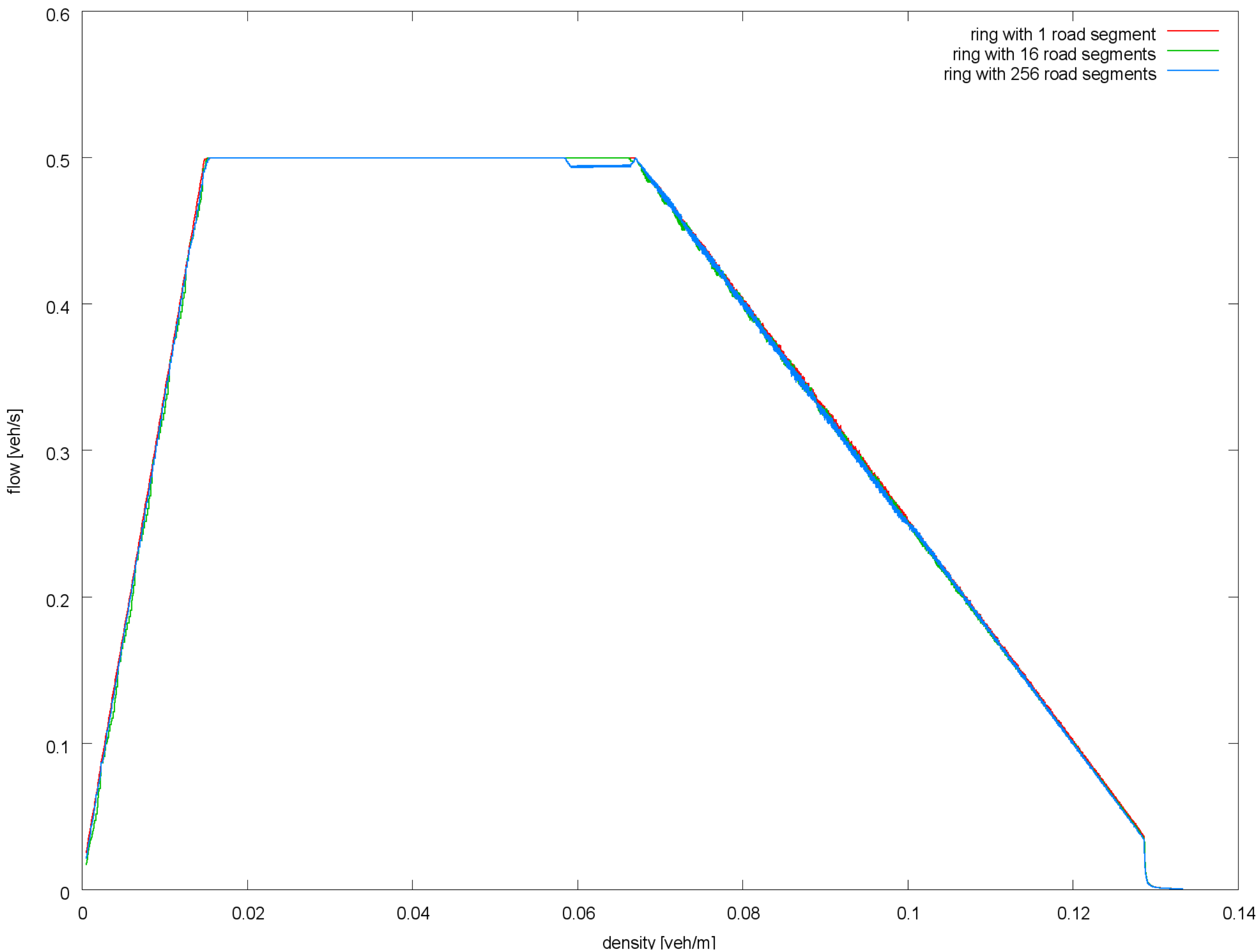
Q-event: Approach with gaps



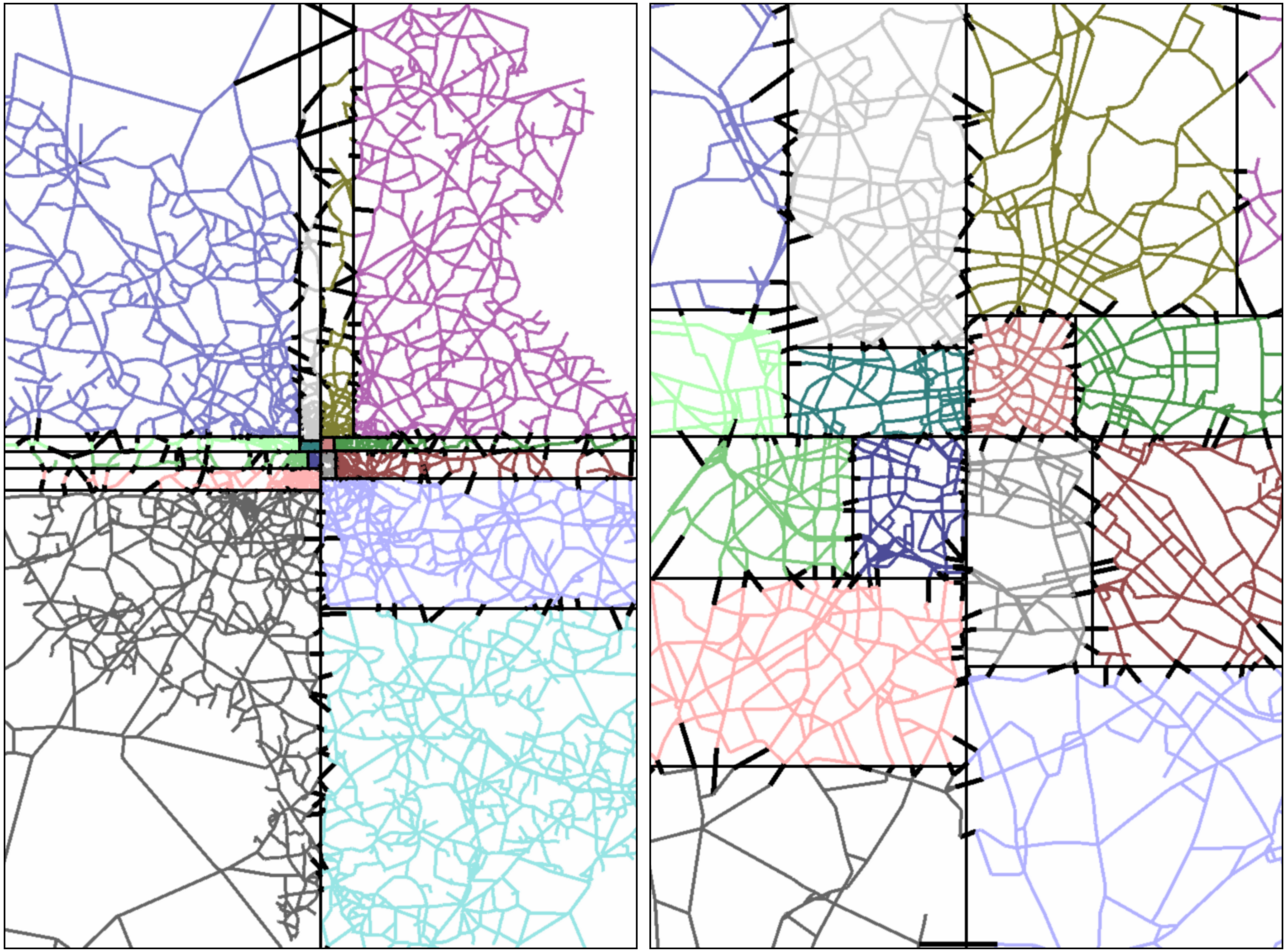
Q-event: Implementation details

- Squeezing to avoid grid-lock
- Inflow capacity = 110% of outflow capacity (1800 veh/h* lanes)
- Vehicles are served in order of arrival at the junctions
- C++ with binary data interface to MATSim-T

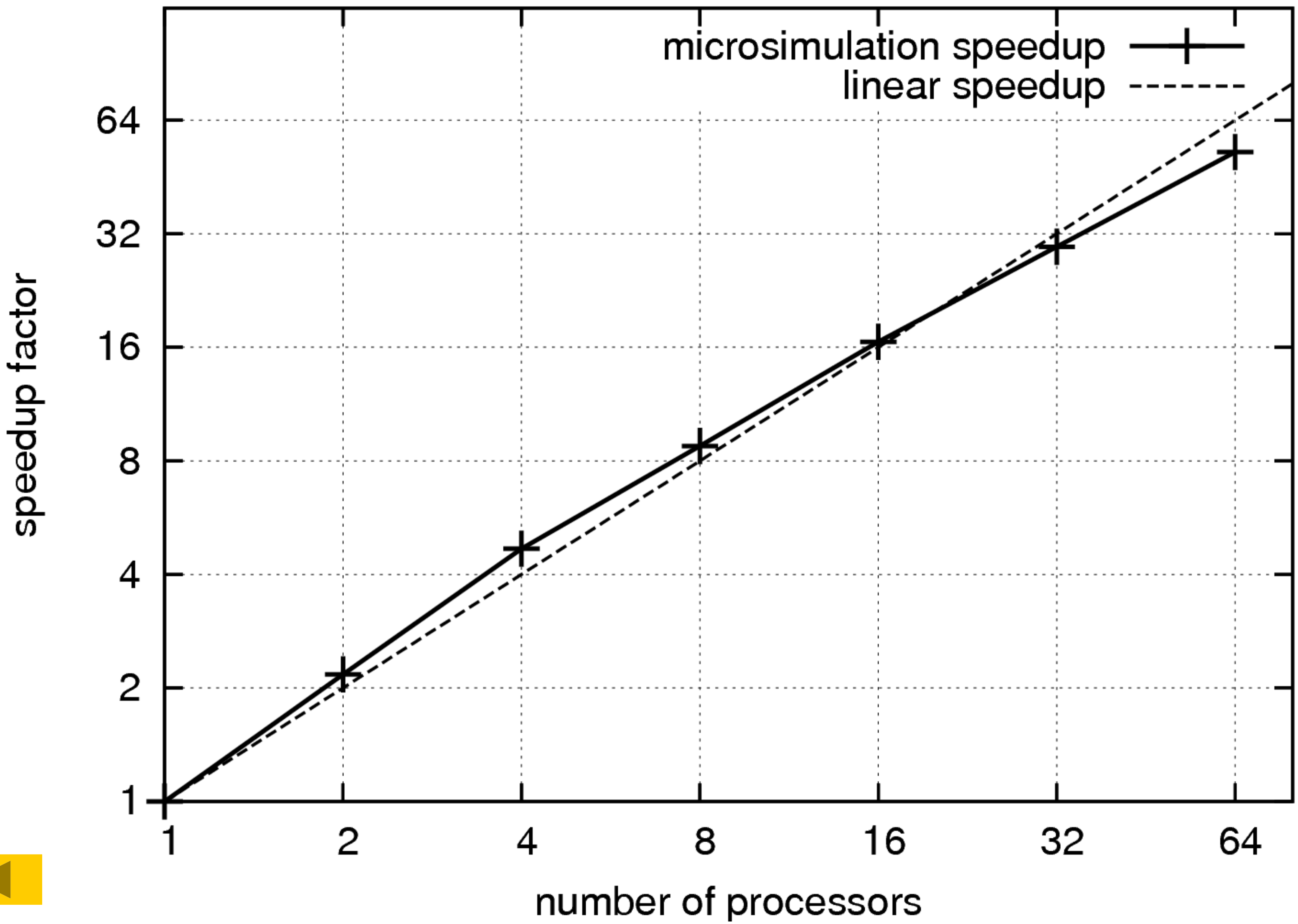
Q-event: Fundamental diagram



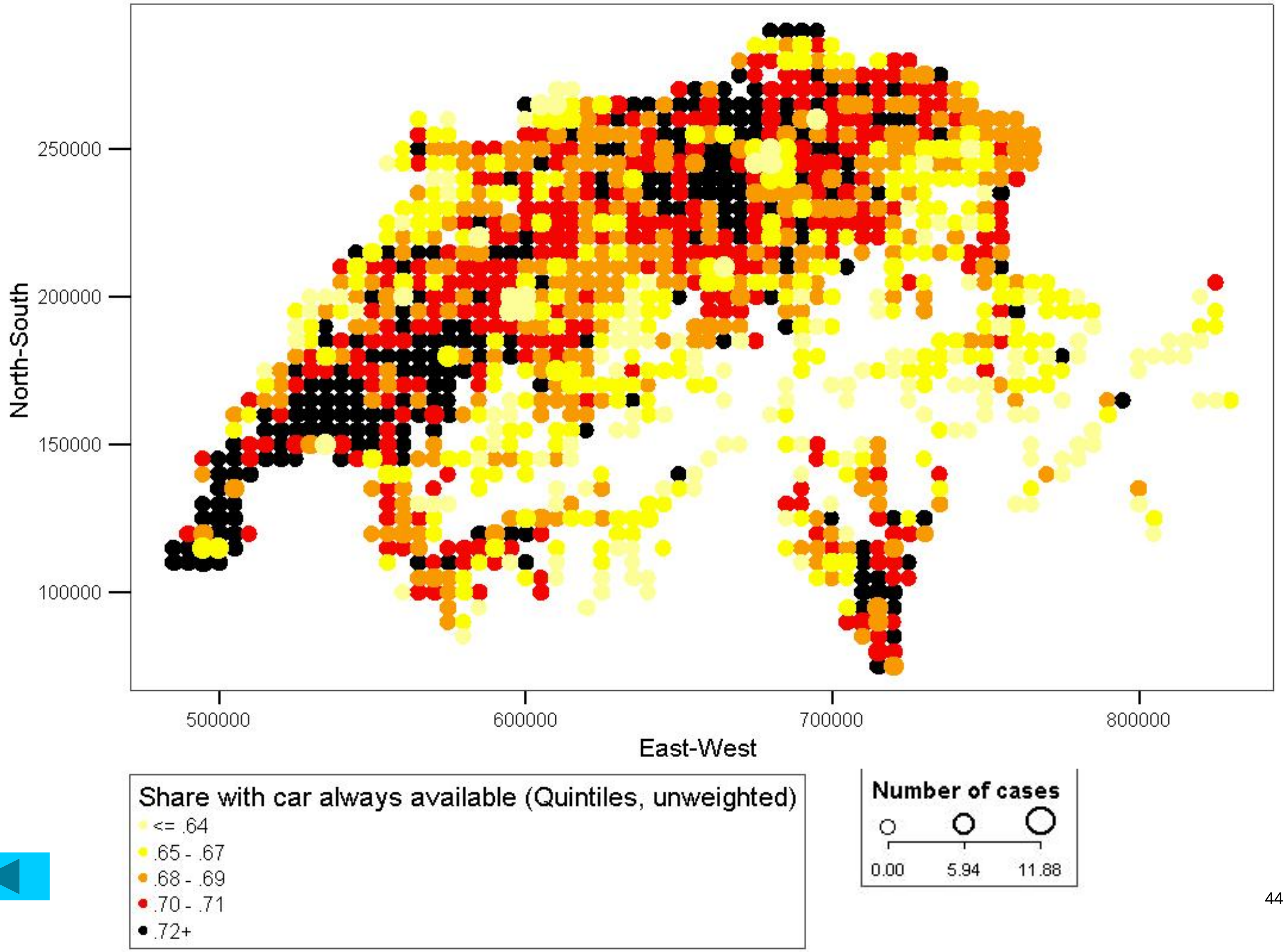
Q-event: Integrated domain decomposition



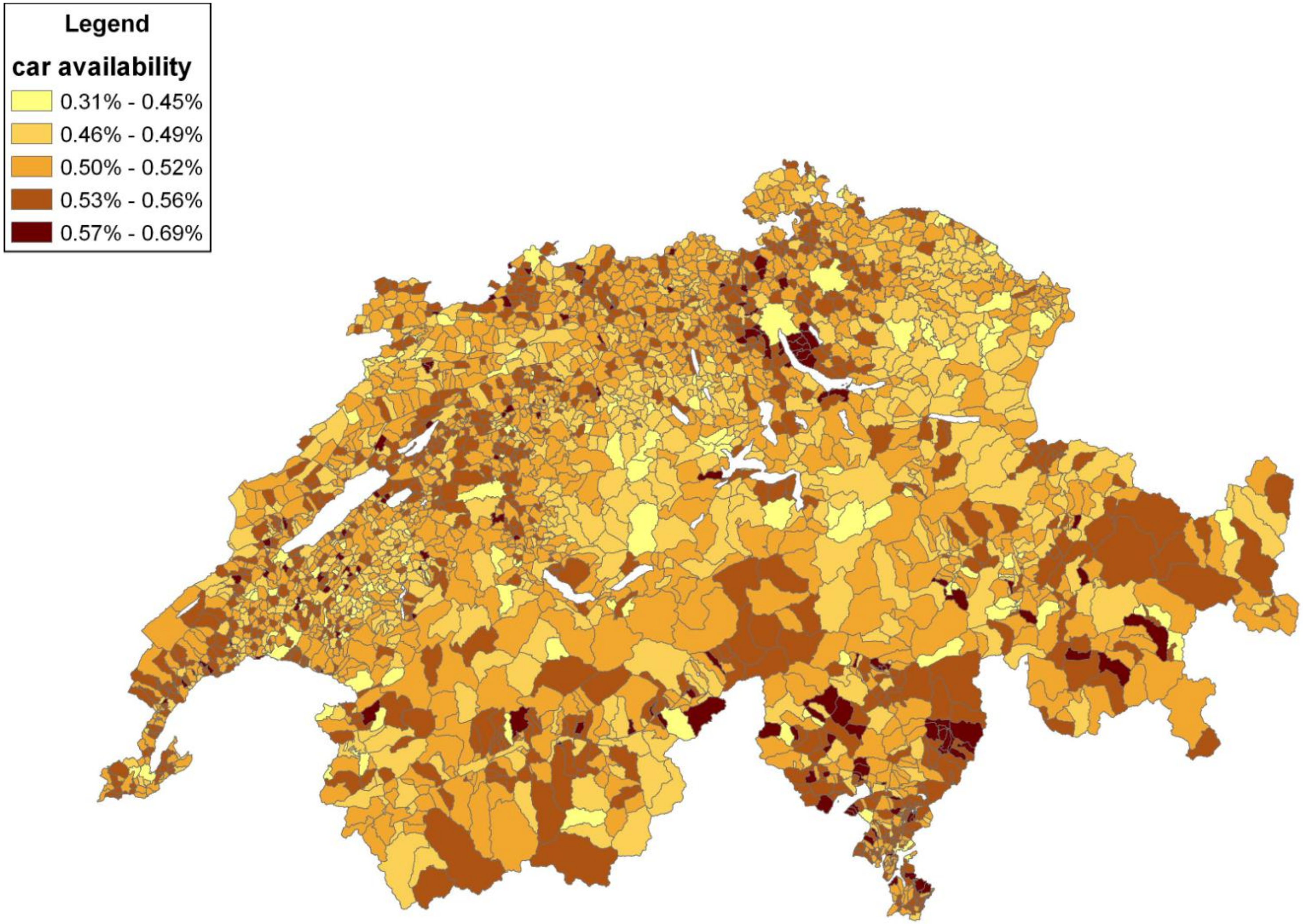
Q-event: Parallelisation



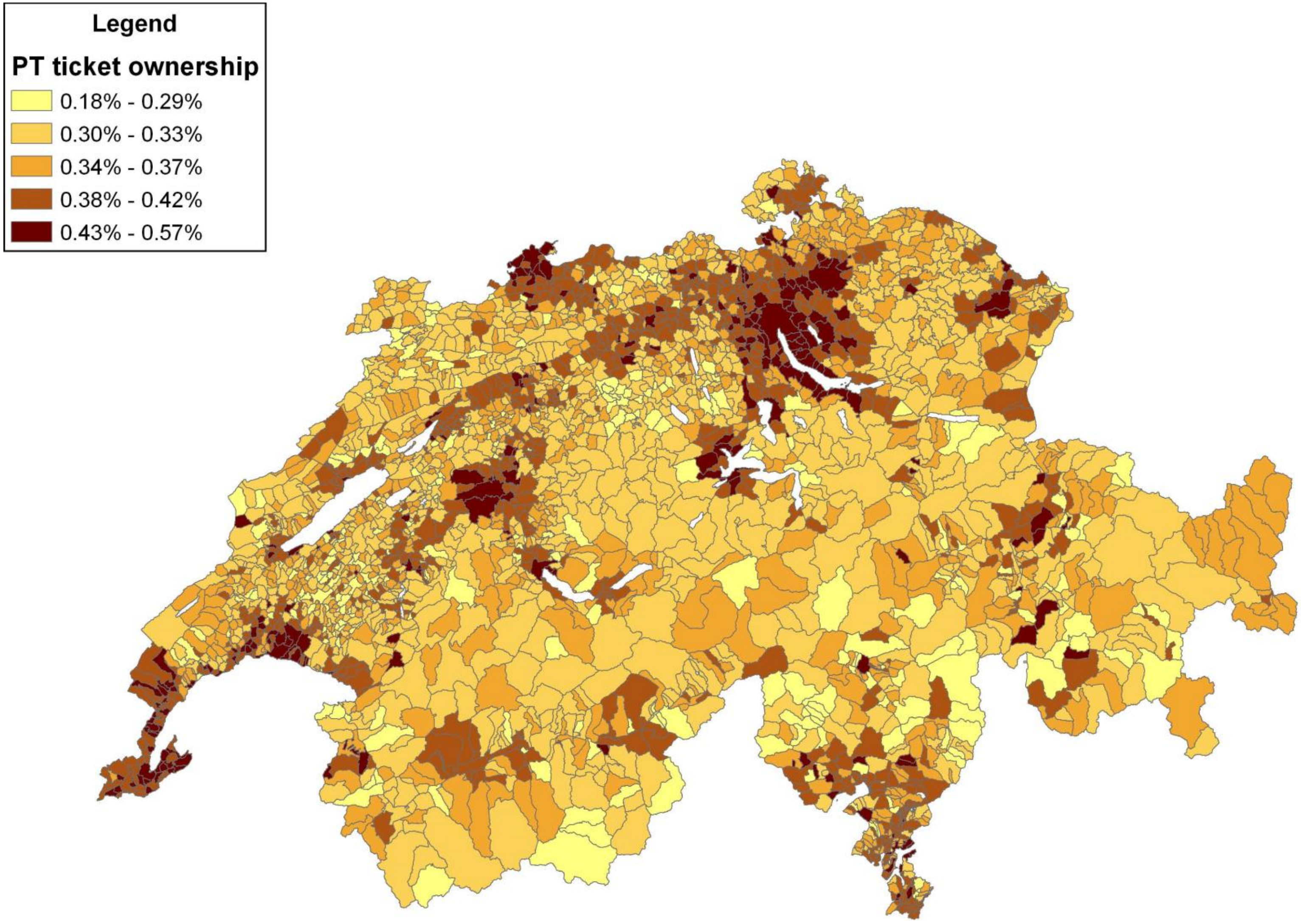
CH: Car availability (Census)



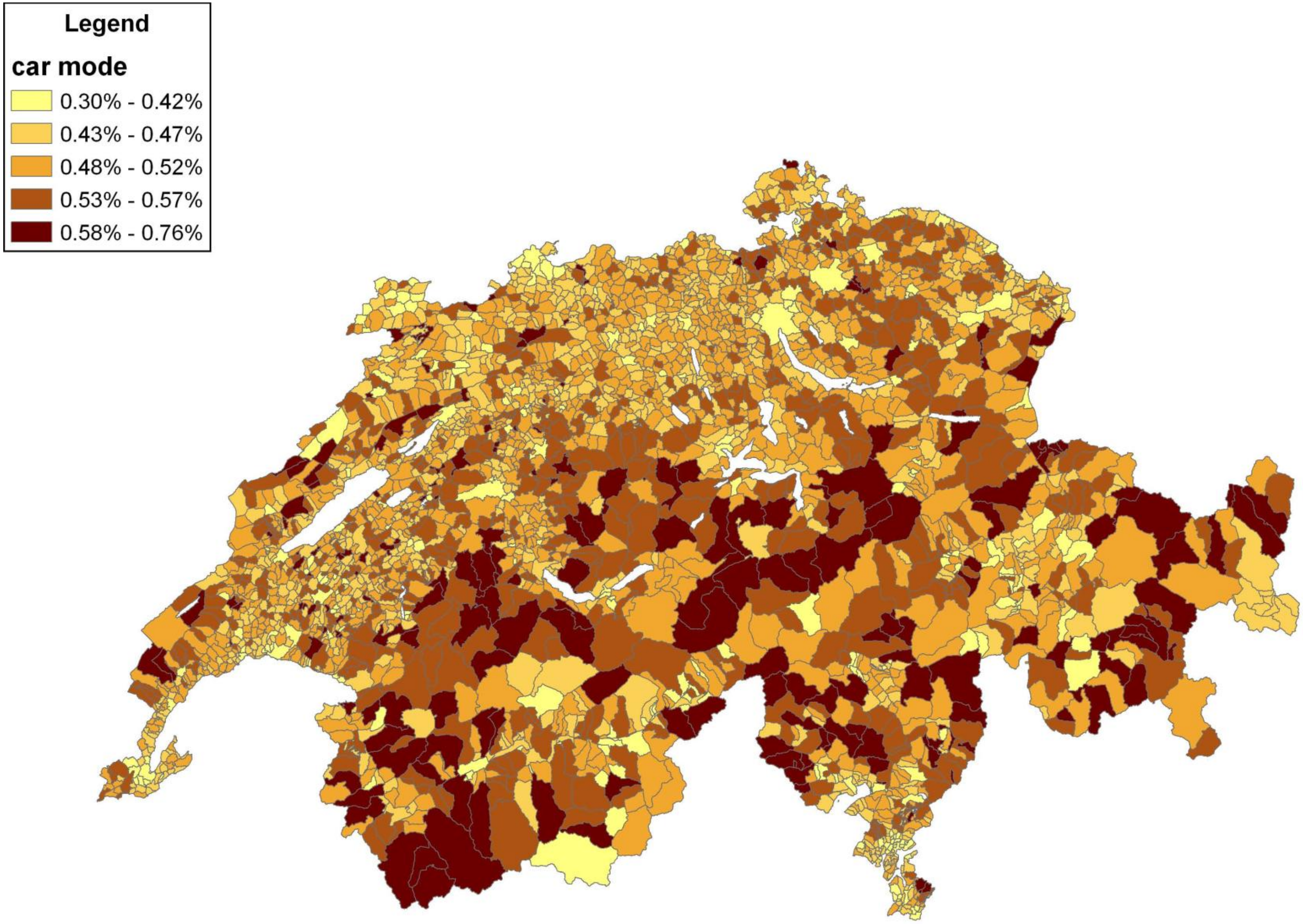
CH: Car availability (modelled)



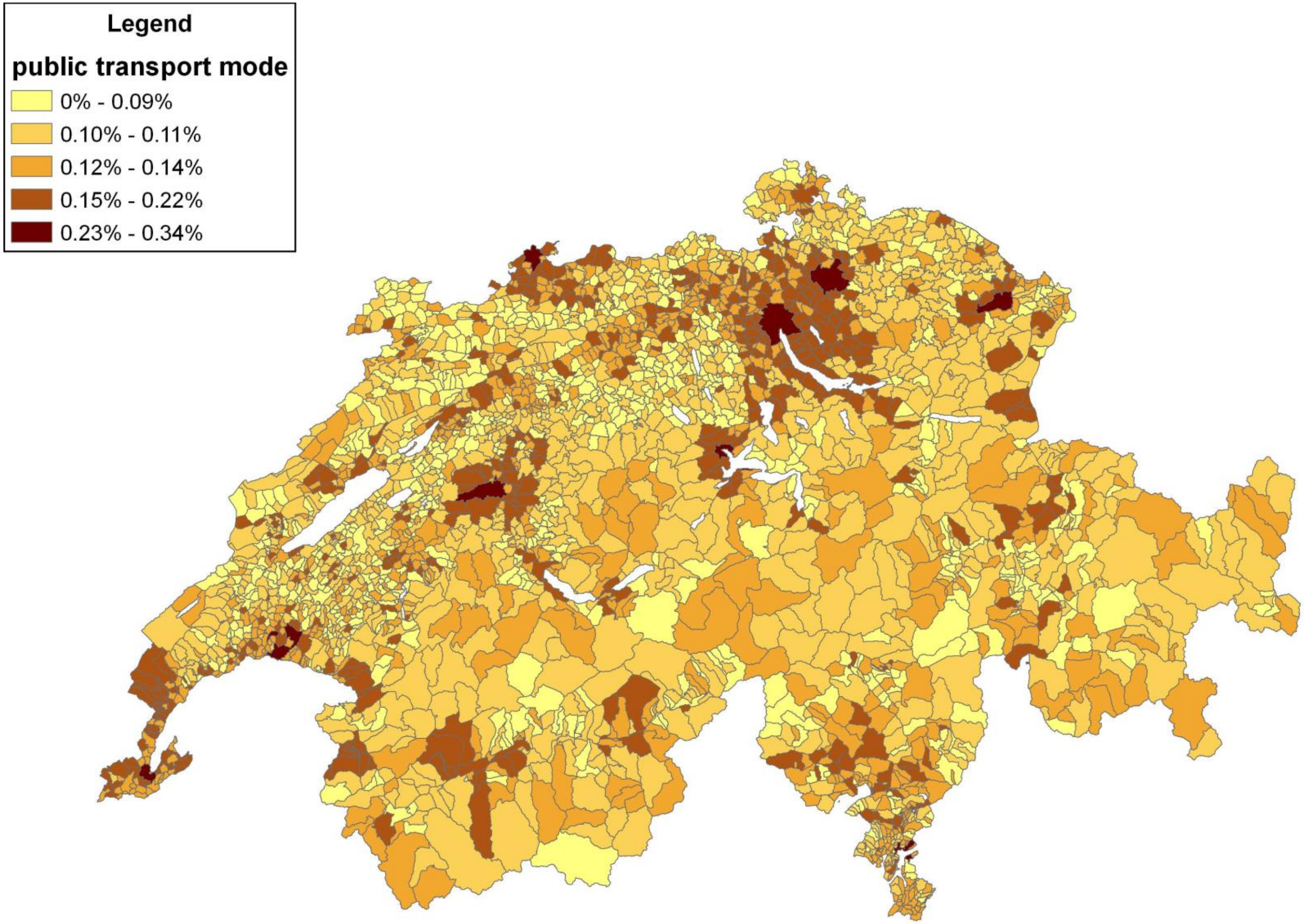
CH: Season ticket ownership (modelled)



CH: tour based mode use – car (modelled)



CH: Tour-based mode use – public transport (modelled)



CH: Mode choice – Observed share public transport