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Agent-based Travel Demand and Traffic Flow Modelling for Mega Cities

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Task

Transport planning models (1)

Are models of

Daily life

reproducing

who is travelling/present

where (location/route/connection)
when
with which vehicle (bike, car, bus, train etc.;)
with whom
for how long
for what purpose
in which daily schedule

Transport planning models (2)

attempt to describe today's and model future network conditions consistent with:

- The given supply of capacity through
  - Networks
  - Services provided on them

- The known/assumed amounts of desired travel
- The known correlations between the behavioural dimensions/structures, capacity and the prices for travel

imposing a justifiable set of assumptions on the solution of the resulting fixed point problem (or not)

Transport planning models (3)

Alternatives:

- Direct demand models (spatial regression models)
- Aggregate (static/dynamic) models
- Agent-based dynamic activity – based models (ABM) + static assignment
- Agent-based dynamic travel demand and traffic flow models

Scale:

- Number of agents/segments
- Number of locations/zones
- Number of mode specific links
- Number of mode specific nodes
- Number of modes
- Number of time segments

Transport planning models (4)

Trade-off between:

- Expert time (learning effort)
- Implementation time (data and calibration)
- Time to answer
  - Scenario definition
  - Quality of UE/SUE
  - Computation time for given quality level
- Time to analyse and present the results
- Time to establish trust in the results among the
  - Experts
  - Policy advisers
  - Decision makers
  - Public

- Uses outside transport planning

Thinking about equilibrium

DUE, SO & SUE

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

up to the resolution of the agents, links and facilities

Matching the

Expected elasticities with respect to the generalized costs

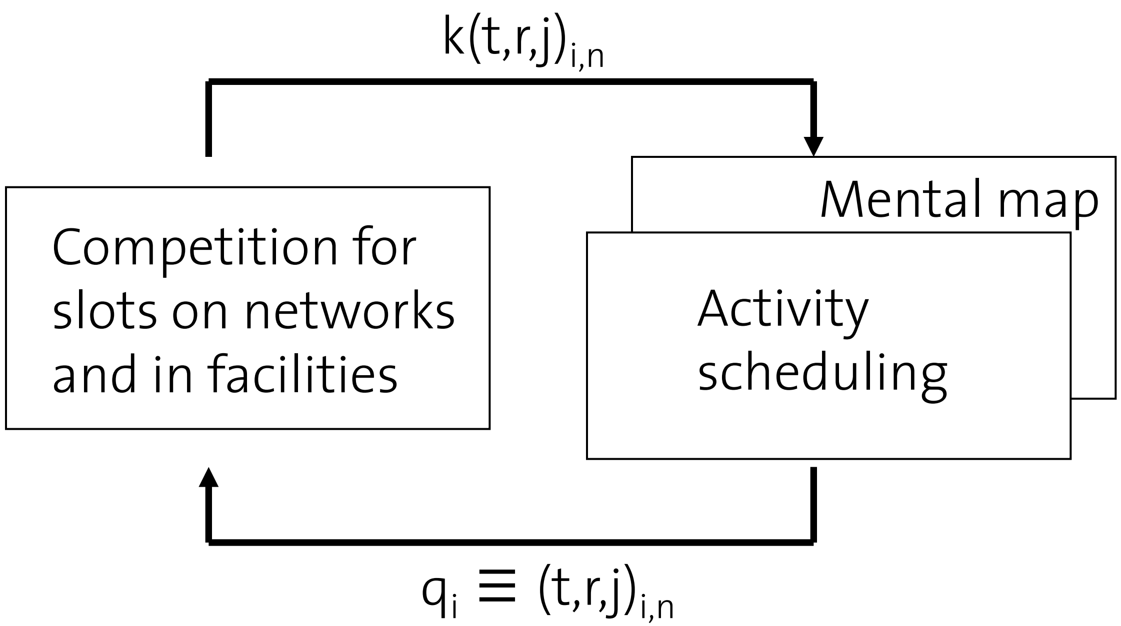
Known correlations between the details of the plans

Capacity constraints on the links, services and facilities

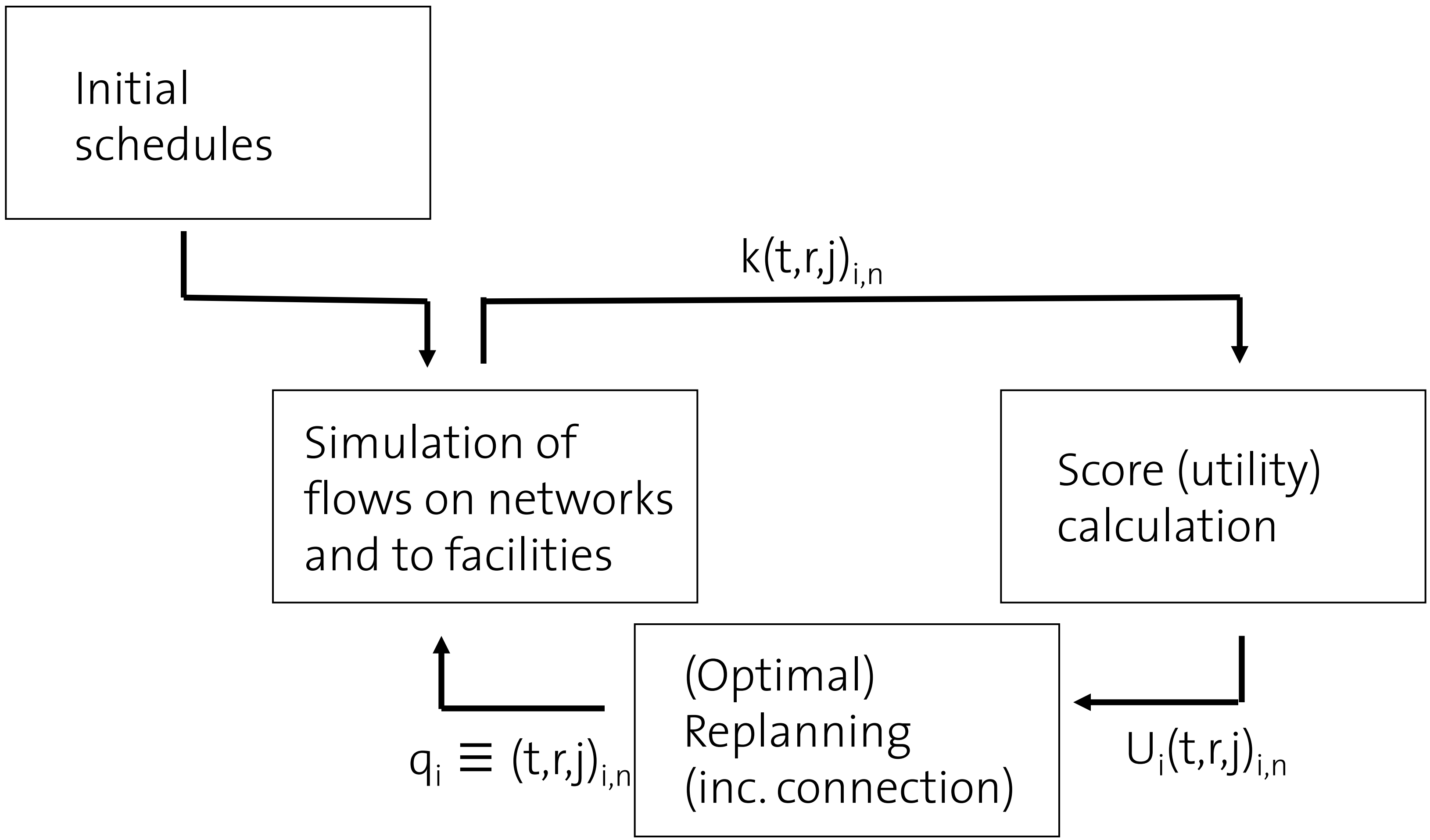
Minimum loads for some of the facilities

How to find the SUE in an agent-based approach ?

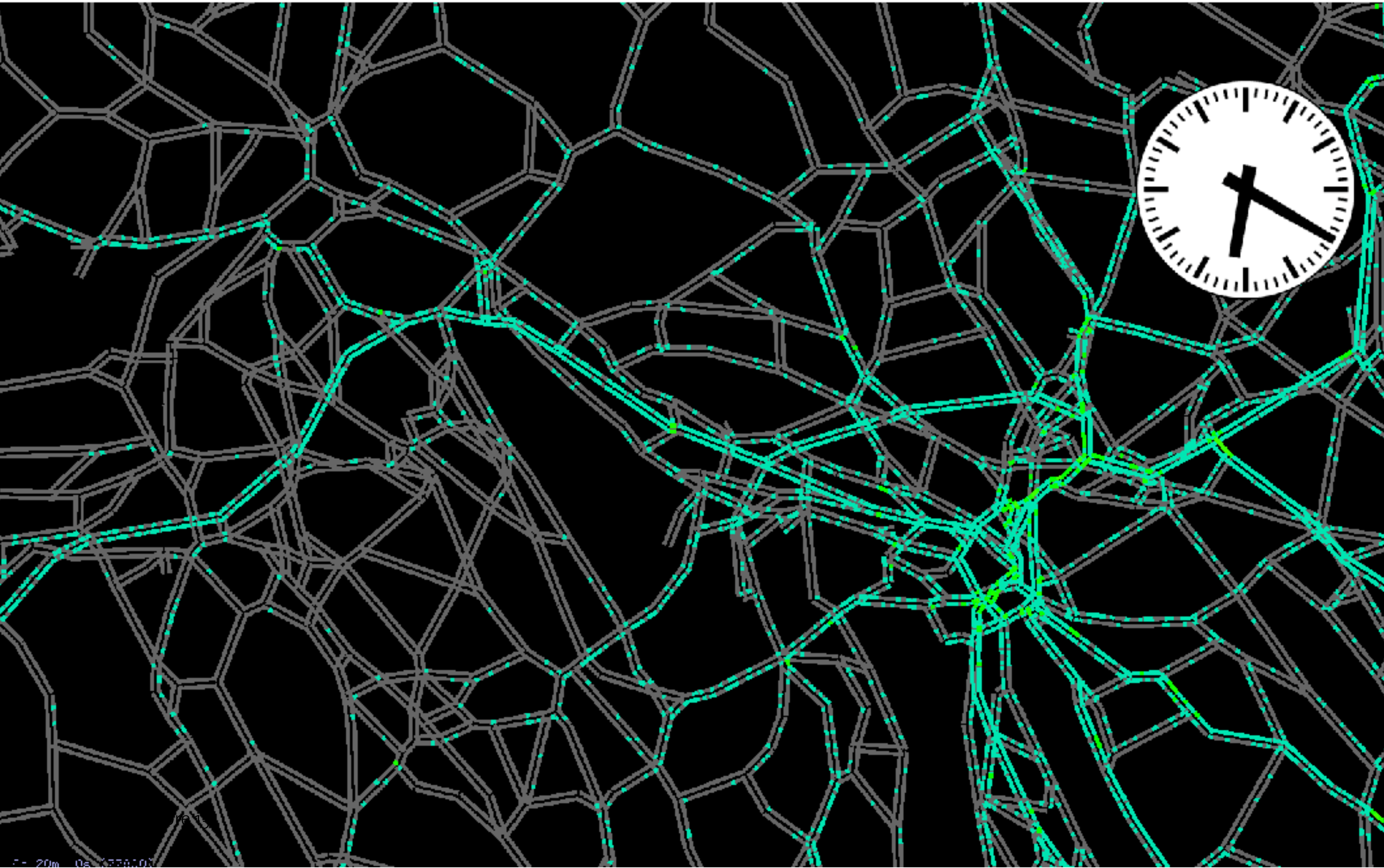
Learning approach of the generic one-day transport model



Equilibrium search in MATSim



Following the agents



MATSim: Logic of the co-evolution – Step 0

Agent 1

Plan 1.1 H-W-H; 8:00, 17:00; C,C;

Agent 2

Plan 2.1 H-W-H; 8:00, 17:00; C,C;

Agent 3

Plan 3.1 H-W-H; 8:00, 17:00; C,C;

Co-evolution – Step 1.1 – Simulation/scoring

Agent 1

Plan 1.1	H-W-H; 8:00, 17:00; C,C;	35

Agent 2

Plan 2.1	H-W-H; 8:00, 17:00; C,C;	35

Agent 3

Plan 3.1	H-W-H; 8:00, 17:00; C,C;	35

Co-evolution – Step 1.2 – After replanning (1/3)

Agent 1		
Plan 1.1	H-W-H; 8:00, 17:00; C,C;	35
Agent 2		
Plan 2.1	H-W-H; 8:00, 17:00; C,C;	35
Agent 3		
Plan 3.1	H-W-H; 8:00, 17:00; C,C;	35
Plan 3.2	**H-W-H; 8:15, 17:30; C,C**	

Co-evolution – Step 1.3 – After plan selection (best/MNL)

Agent 1		
Plan 1.1	H-W-H; 8:00, 17:00; C,C;	**100%**
Agent 2		
Plan 2.1	H-W-H; 8:00, 17:00; C,C;	**100%**
Agent 3		
Plan 3.1	H-W-H; 8:00, 17:00; C,C;	35
Plan 3.2	H-W-H; 8:15, 17:30; C,C;	**New**

Co-evolution – Step 2.1 – Simulation/scoring

Agent 1		
Plan 1.1	H-W-H; 8:00, 17:00; C,C;	**45**
Agent 2		
Plan 2.1	H-W-H; 8:00, 17:00; C,C;	**45**
Agent 3		
Plan 3.1	H-W-H; 8:00, 17:00; C,C;	35
Plan 3.2	H-W-H; 8:15, 17:30; C,C;	**60**

Co-evolution – Step 2.2 – After replanning (1/3)

Agent 1			
	Plan 1.1	H-W-H; 8:00, 17:00; C,C;	45
	Plan 1.2	**H-W-H; 8:00, 17:00; B,B;**	
Agent 2			
	Plan 2.1	H-W-H; 8:00, 17:00; C,C;	45
Agent 3			
	Plan 3.1	H-W-H; 8:00, 17:00; C,C;	35
	Plan 3.2	H-W-H; 8:15, 17:30; C,C;	60

Co-evolution – Step 2.3 – After plan selection (best/MNL)

Agent 1		
Plan 1.1	H-W-H; 8:00, 17:00; C,C;	45
Plan 1.2	H-W-H; 8:00, 17:00; B,B;	**New**
Agent 2		
Plan 2.1	H-W-H; 8:00, 17:00; C,C;	**100%**
Agent 3		
Plan 3.1	H-W-H; 8:00, 17:00; C,C;	**38%**
Plan 3.2	H-W-H; 8:15, 17:30; C,C;	62%

Co-evolution – Step 3.1 – Simulation/scoring

Agent 1		
Plan 1.1	H-W-H; 8:00, 17:00; C,C;	45
Plan 1.2	H-W-H; 8:00, 17:00; B,B;	**70**
Agent 2		
Plan 2.1	H-W-H; 8:00, 17:00; C,C;	**45**
Agent 3		
Plan 3.1	H-W-H; 8:00, 17:00; C,C;	**45**
Plan 3.2	H-W-H; 8:15, 17:30; C,C;	60

Co-evolution – Step 3.2 – After replanning (1/3)

Agent 1		
Plan 1.1	H-W-H; 8:00, 17:00; C,C;	45
Plan 1.2	H-W-H; 8:00, 17:00; B,B;	70
Agent 2		
Plan 2.1	H-W-H; 8:00, 17:00; C,C;	45
Agent 3		
Plan 3.1	H-W-H; 8:00, 17:00; C,C;	45
Plan 3.2	H-W-H; 8:15, 17:30; C,C;	60
Plan 3.3	**H-W-H; 7:30, 17:15; B,B**	

Co-evolution – Step 3.3 – After plan selection (best/MNL)

Agent 1			
	Plan 1.1	H-W-H; 8:00, 17:00; C,C;	36%
	Plan 1.2	H-W-H; 8:00, 17:00; B,B;	**64%**
Agent 2			
	Plan 2.1	H-W-H; 8:00, 17:00; C,C;	**100%**
Agent 3			
	~~Plan 3.1~~	~~H-W-H; 8:00, 17:00; C,C;~~	~~45~~
	Plan 3.2	H-W-H; 8:15, 17:30; C,C;	60
	Plan 3.3	H-W-H; 7:30, 17:15; B,B	**New**

(The (worst) plan more then memory allows is deleted)

Co-evolution – Summary of best scores

	Iteration 1	Iteration 2	Iteration 3
Agent 1	35	45	80
Agent 2	35	45	45
Agent 3	35	60	60
Mean	**35**	**50**	**62**

MATSim today

Activity scheduling dimensions

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

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

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

Modelling Switzerland 2009

2009 MATSim Switzerland: Configuration

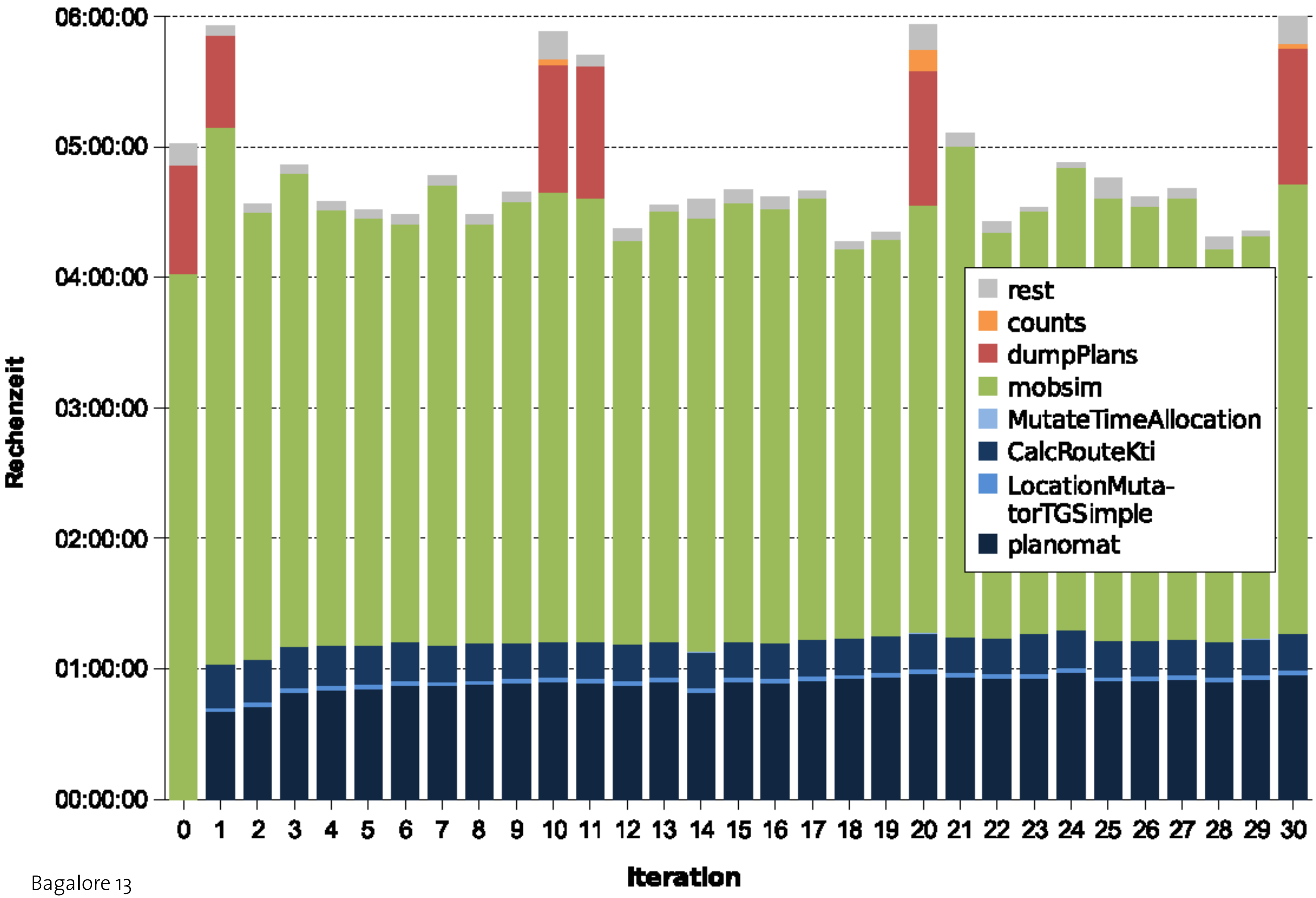
During the iterations:

- 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:

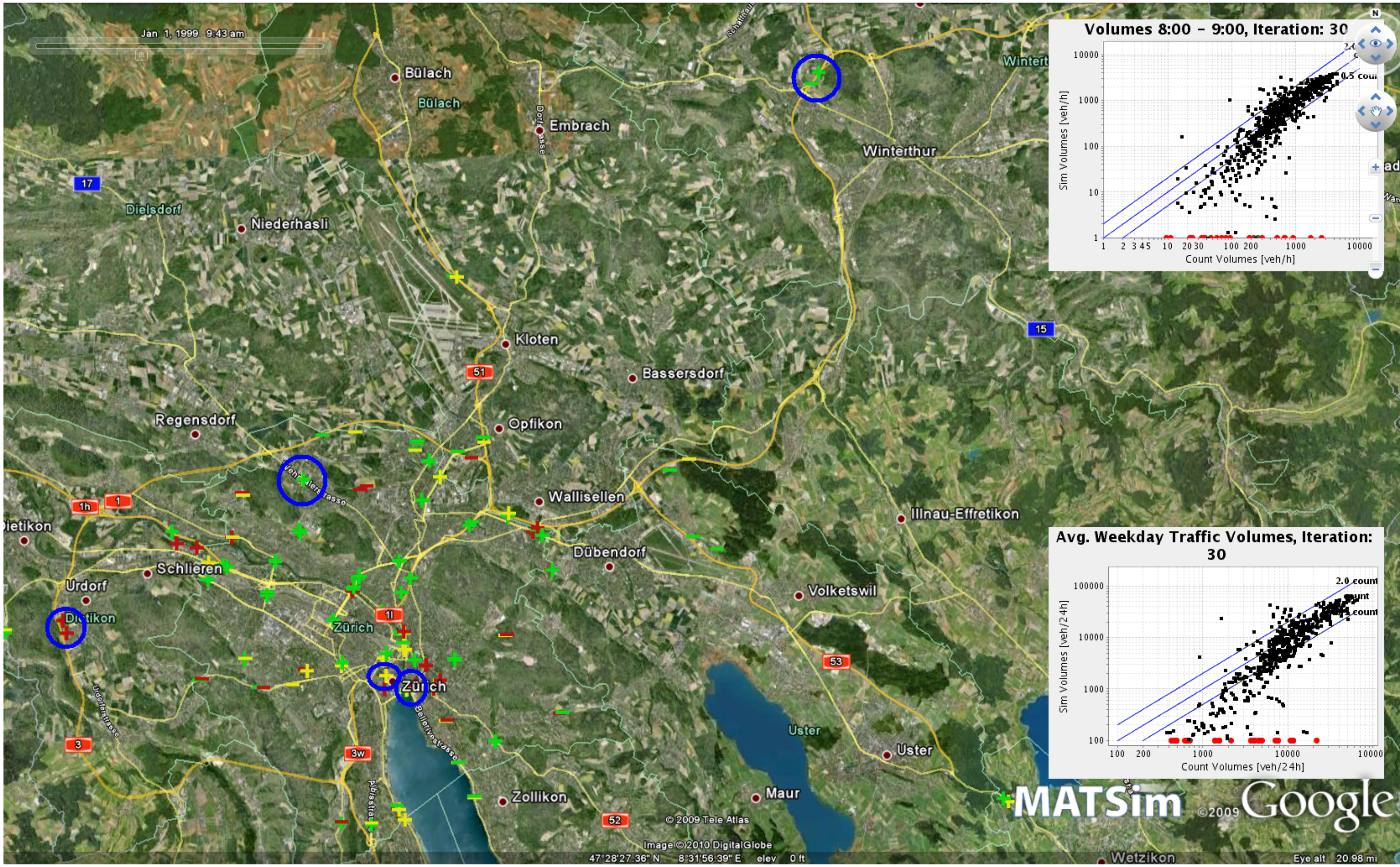
- $6.0 * 10^6$ agents with 11 activity types
- $1.6 * 10^6$ facilities
- $0.8 * 10^6$ links
- 24 * 60 * 60 seconds

2009 MATSim Switzerland: Computing time

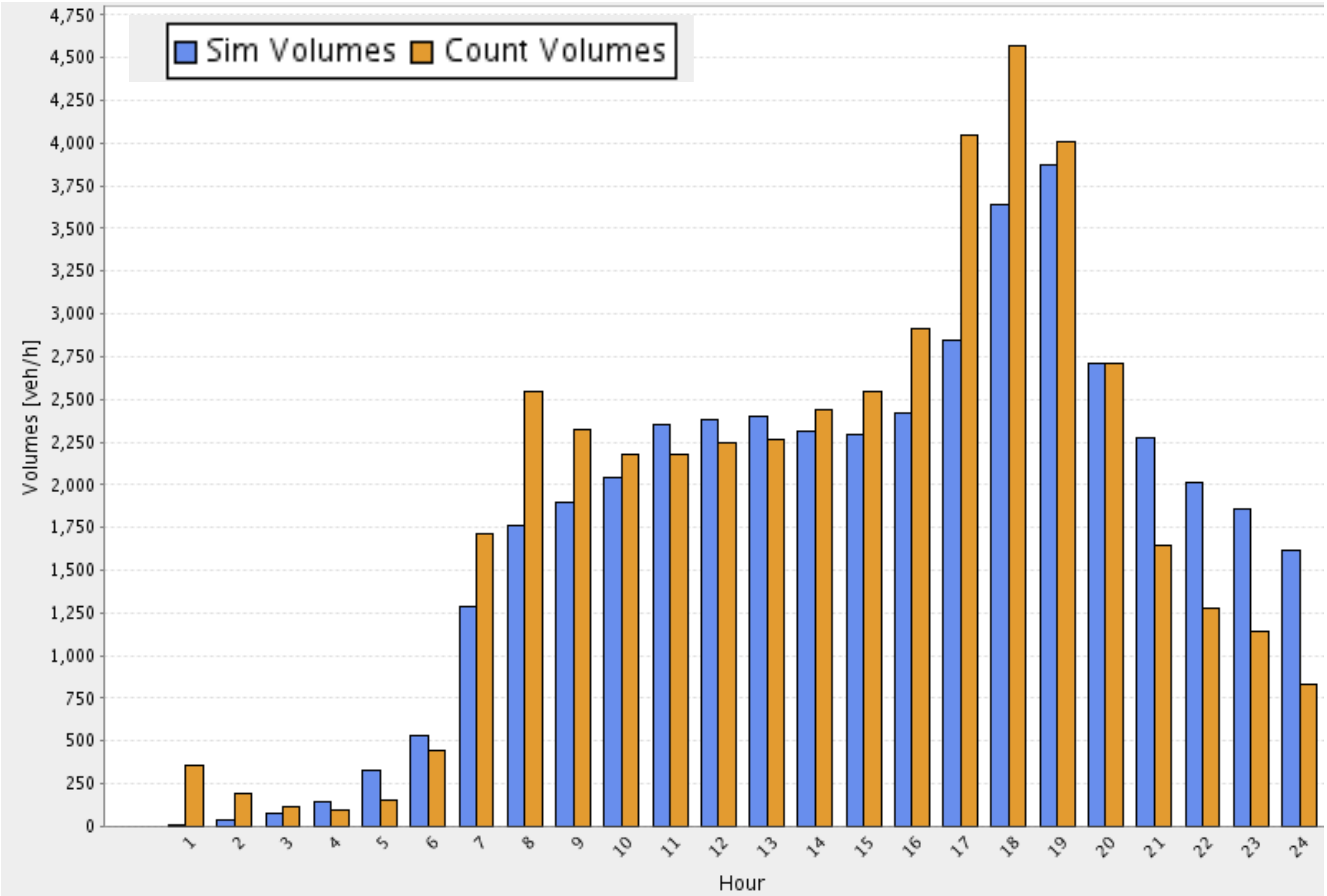


Balmer, 2009

Quality of the results: Overall counts



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



MATSim: A GNU public licence software project

MATSim: A GNU public licence software project

Main partners

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

Coordination via:

- User meeting
- Conceptual meeting
- Developer meeting

- Code committee
- Regular releases of the code

Current progress: Berlin

Network: 113 000 links

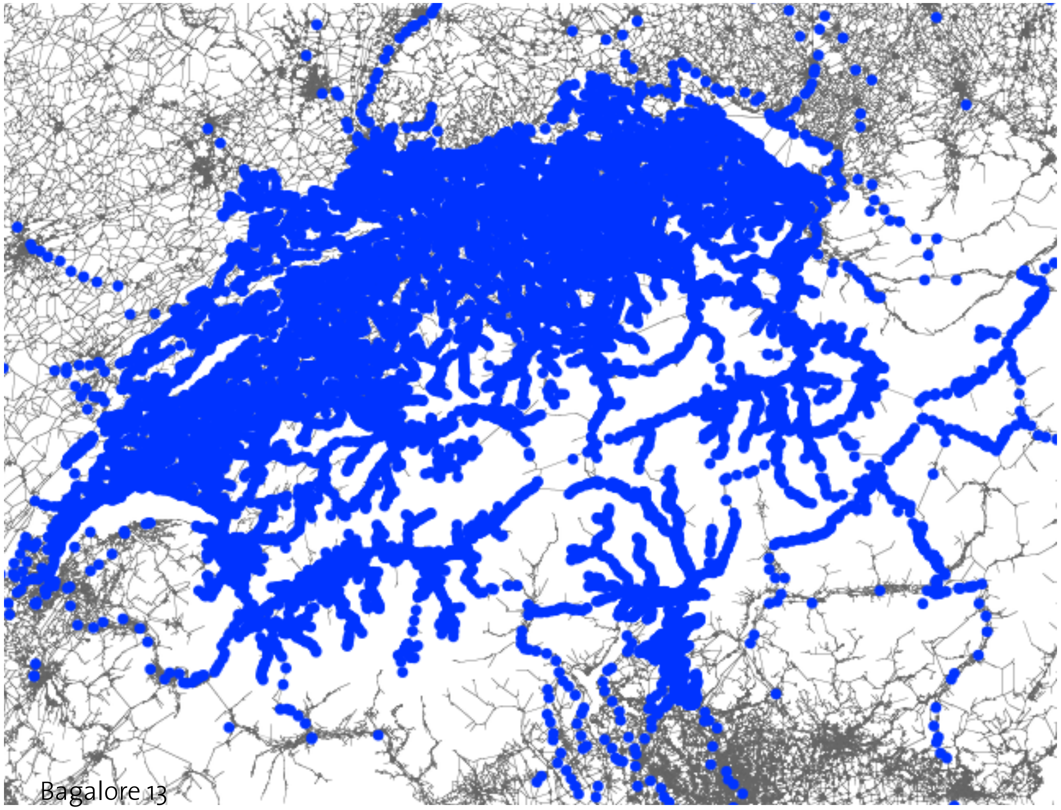
Population: 4,5 million agents

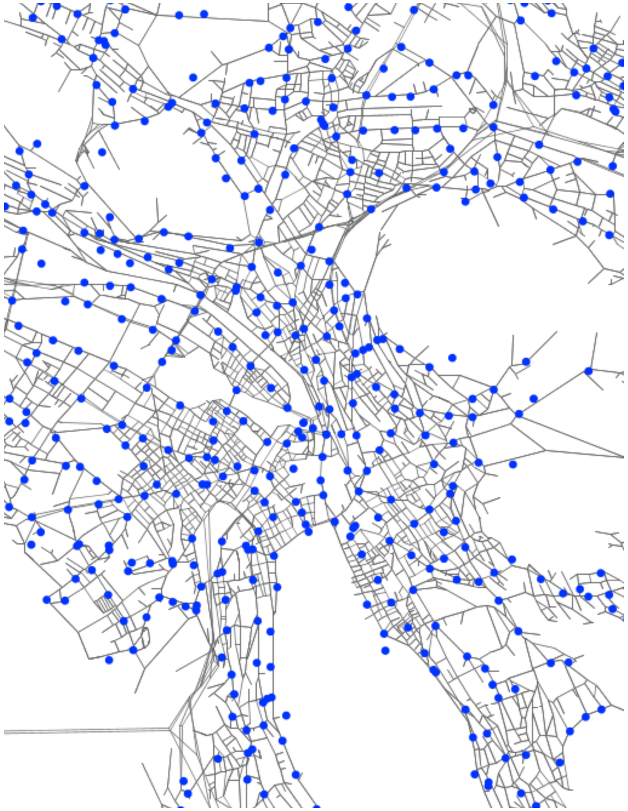
Public Transport: 530 lines, 96 transit vehicle types

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 (Feil)
Sequence of activities (Ordonez)

- **Start and duration of activity**
- Composition of the group undertaking the activity **(Kowald, Tan, Fourie)**
- Expenditure division
- **Location of the activity** **(Horni)**
  - Movement between sequential locations
    - **Location of access and egress from the mean of transport**
      - Parking search and type **(Waraich)**
    - **Vehicle/means of transport** **(Ciari)**
    - **Route/service** **(Chakirov)**
    - Group travelling together **(Dubernet, Fourie)**
    - Expenditure division

Singapore extensions: Allocating work locations

Source: maps.google.com

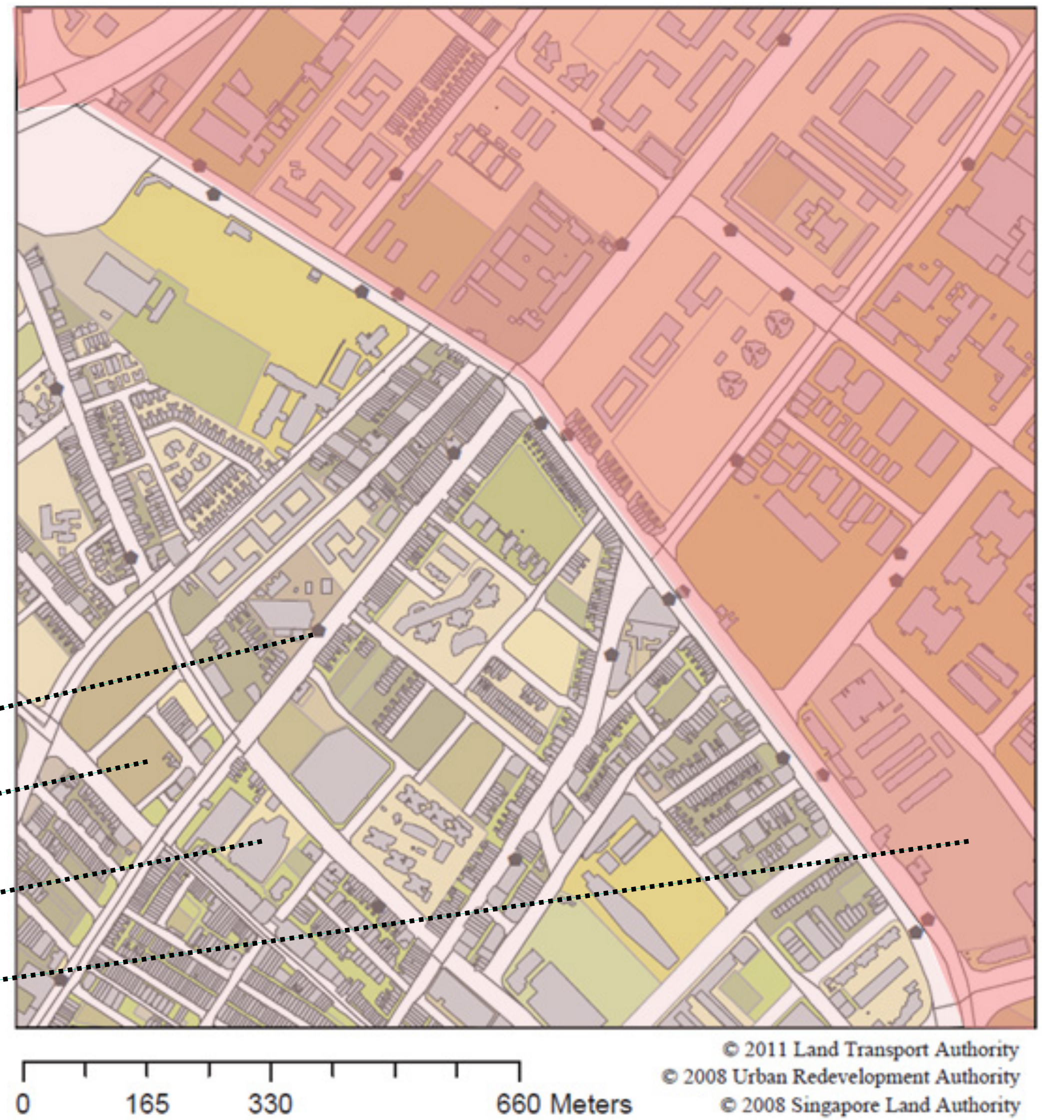
Work location model: motivation and idea

Background:

- Number and location of work activities is crucial for transport modeling
- No enterprise census
- Business registration files problematic for actual work location estimation

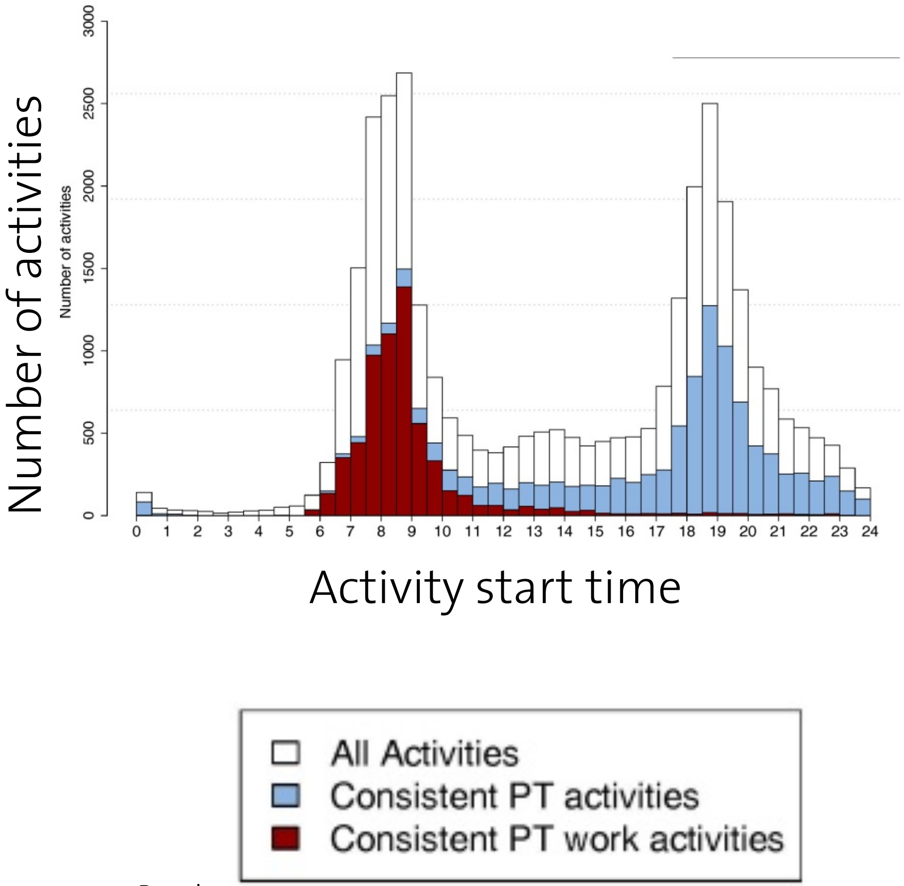
Combination of various data sources:

- Boarding and alighting activities at stops
- Land use type and gross plot ratio
- Building foot print
- Mode share

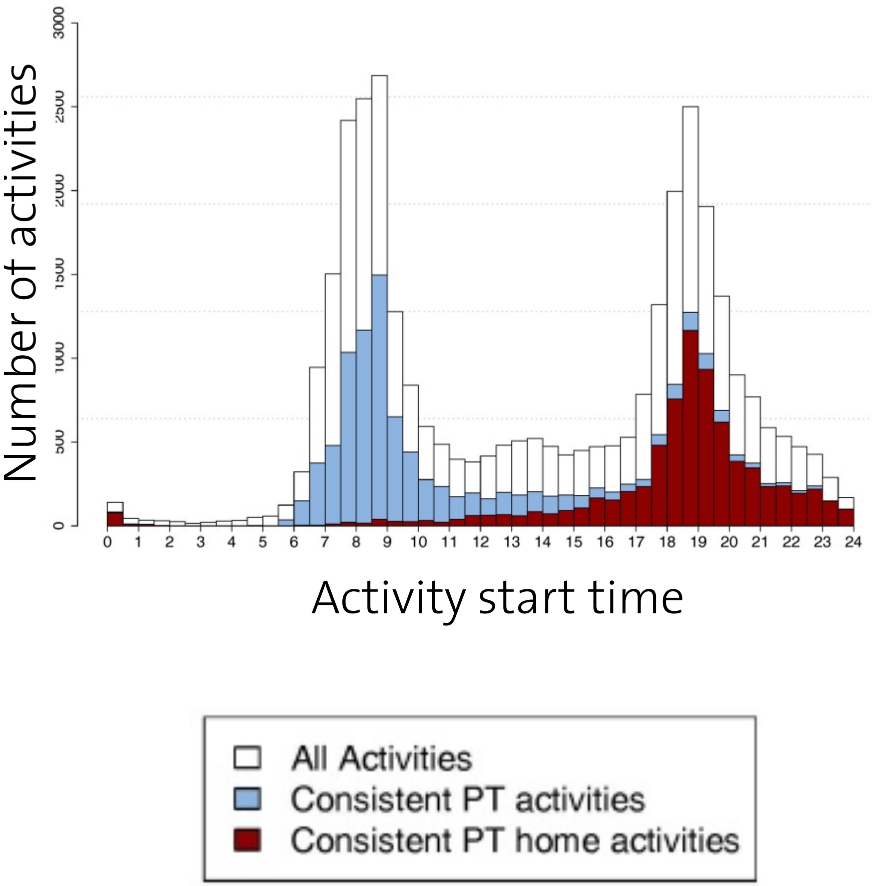


Detection of work activities: start time

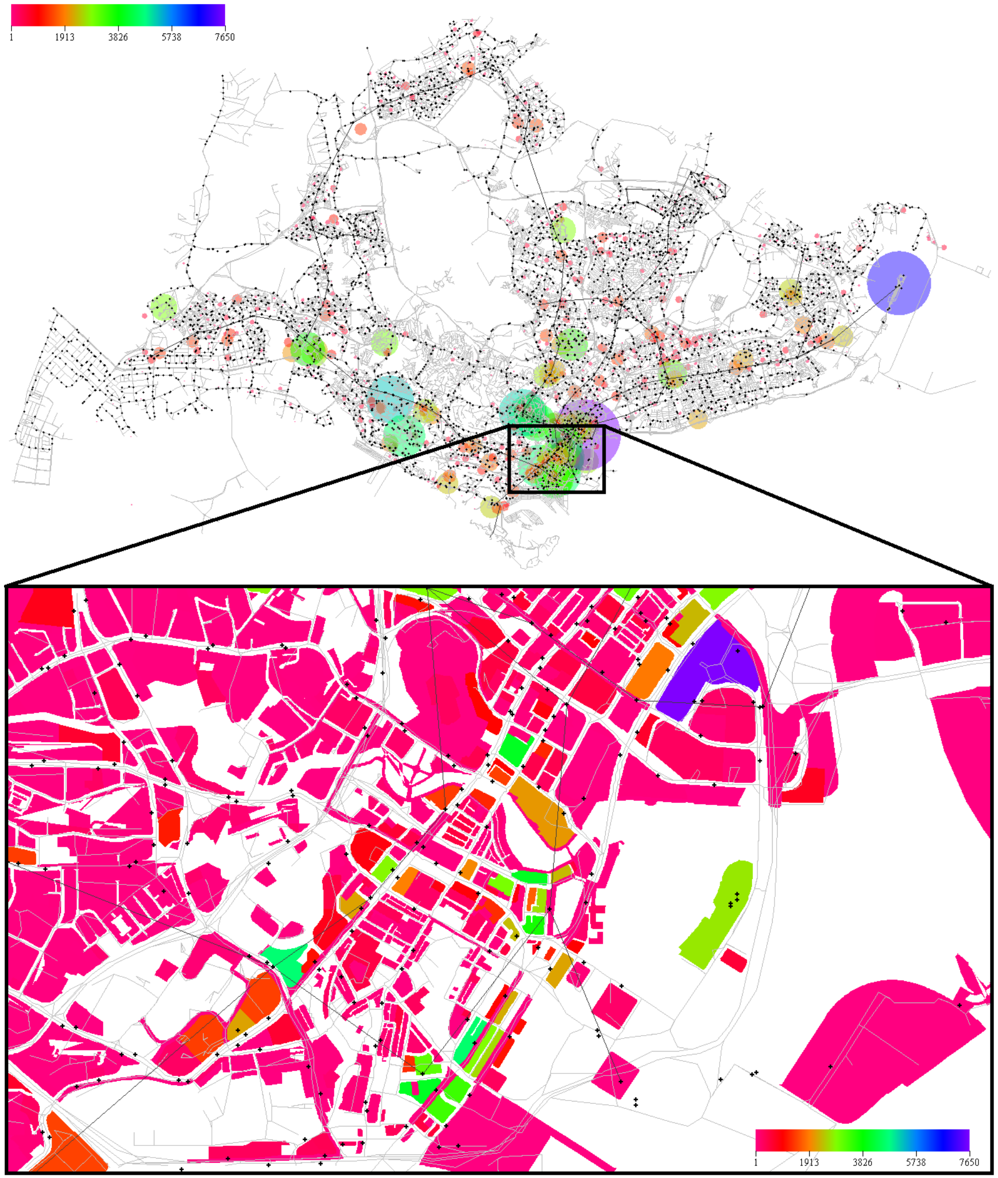
Work activities



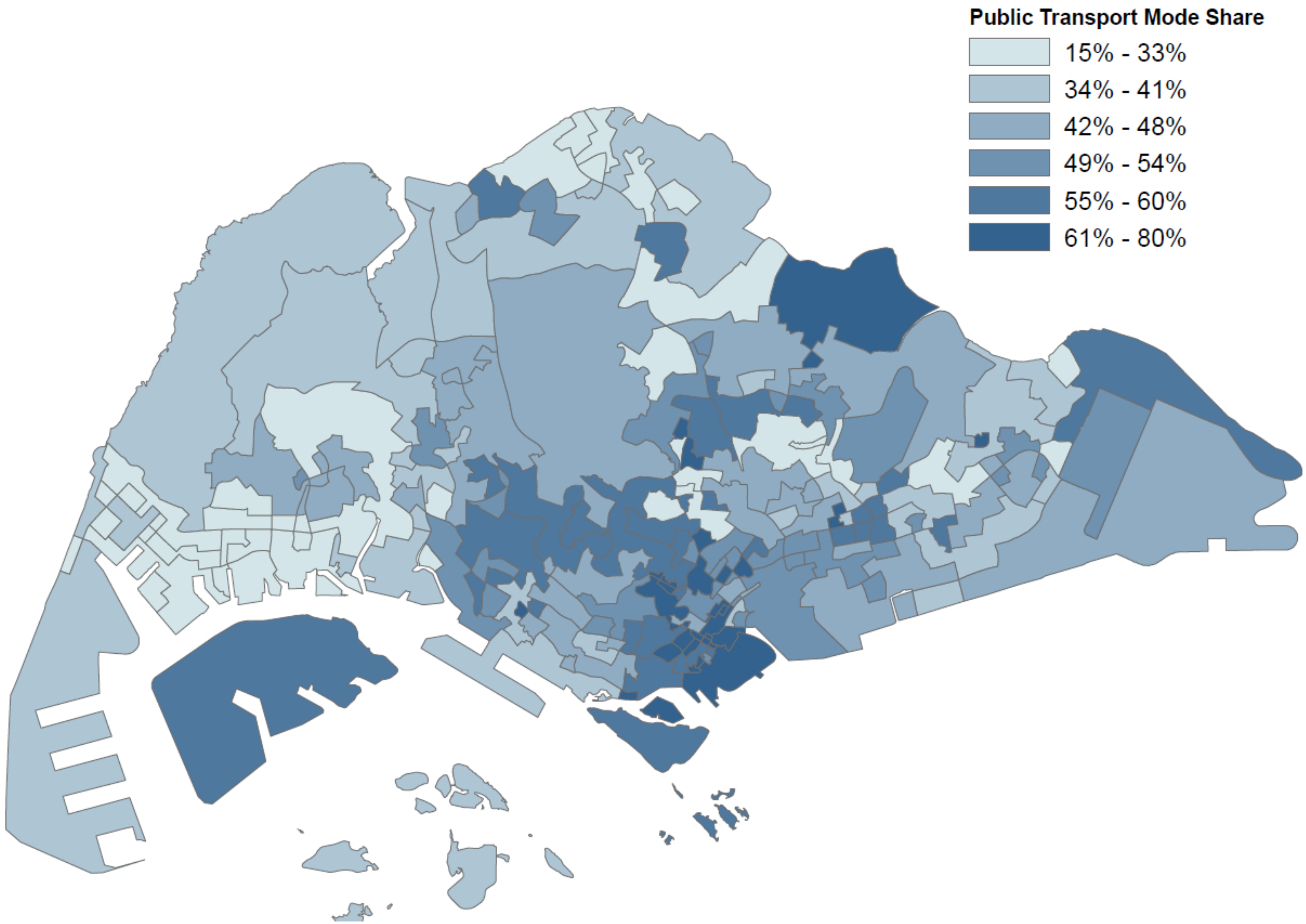
Home activities



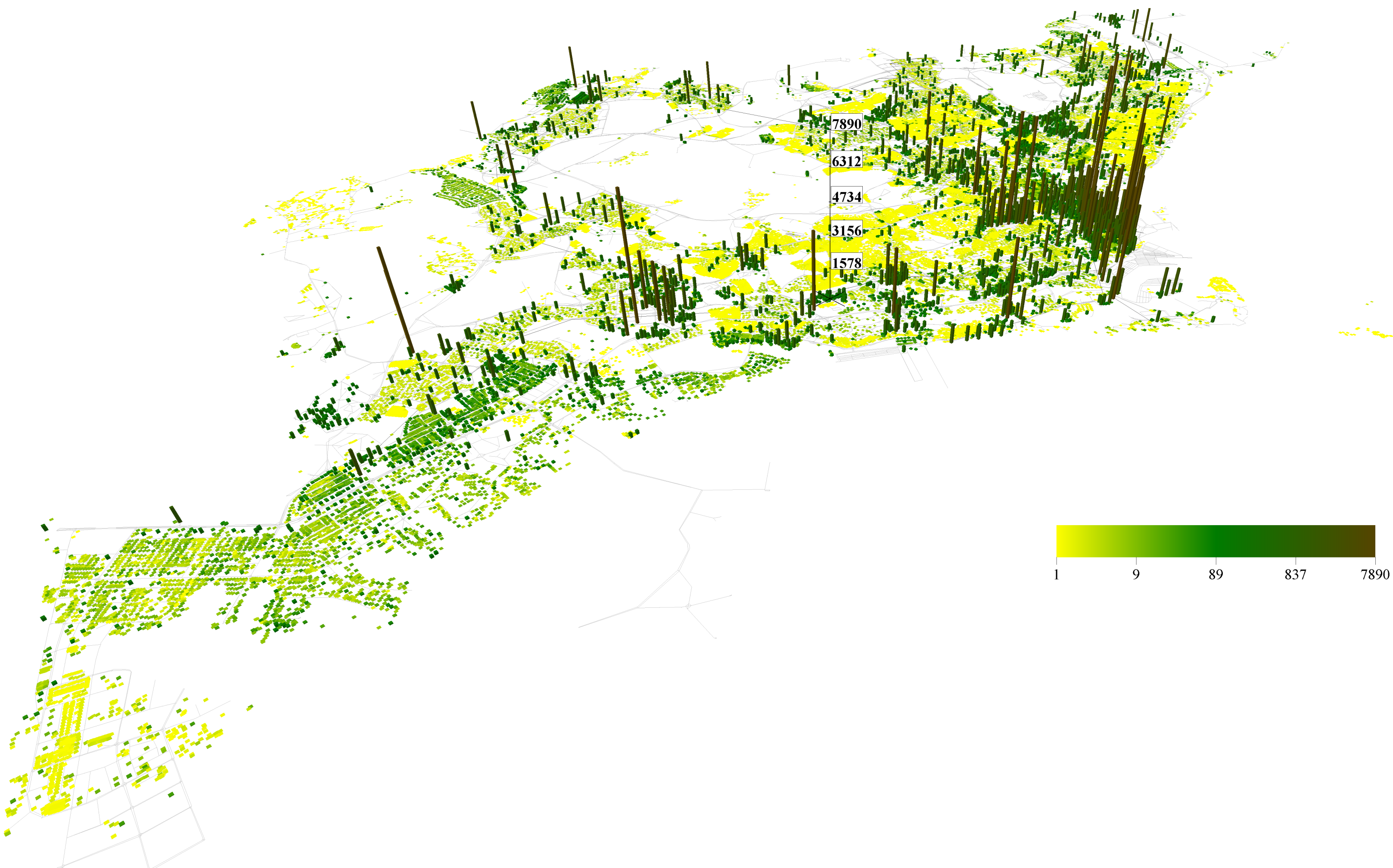
Applying to public transport smart card records



Scaling by mode shares as observed from travel diary



Distribution to single buildings



Ordonez, S and A. Erath (2012) Estimating Dynamic Workplace Capacities using Public Transport Smart Card Data and a Household Travel Survey

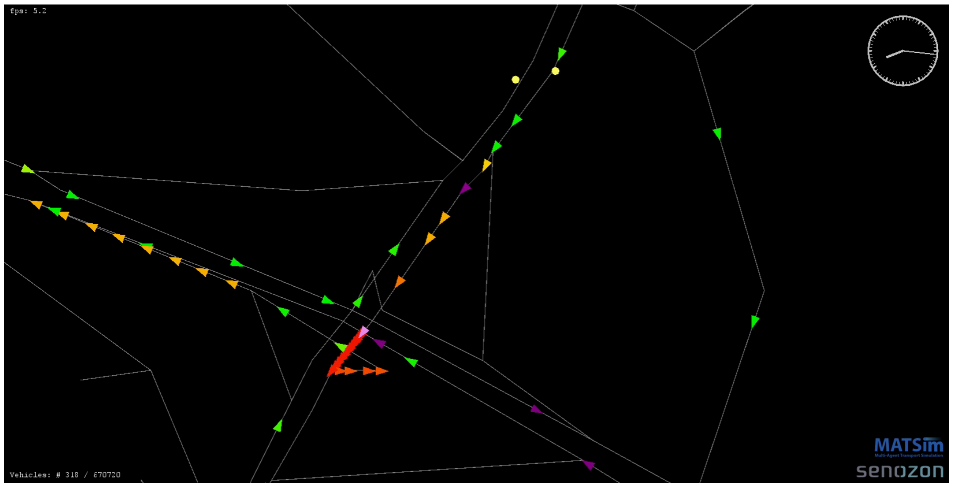
Singapore extensions: Interaction between car and buses

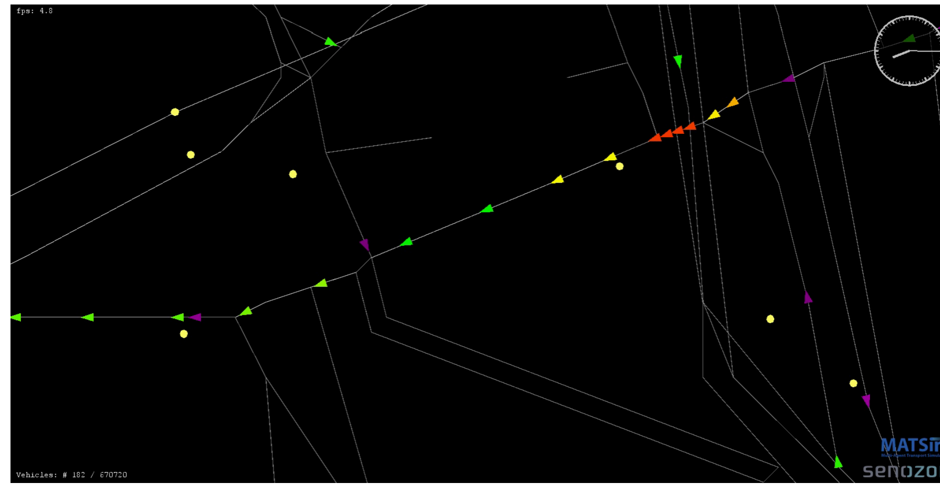
Source: maps.google.com

Interaction between car and buses (purple)

Without buslane:
Adam Rd / PIE

With buslane:
Gelyang Rd, aft Sims Way



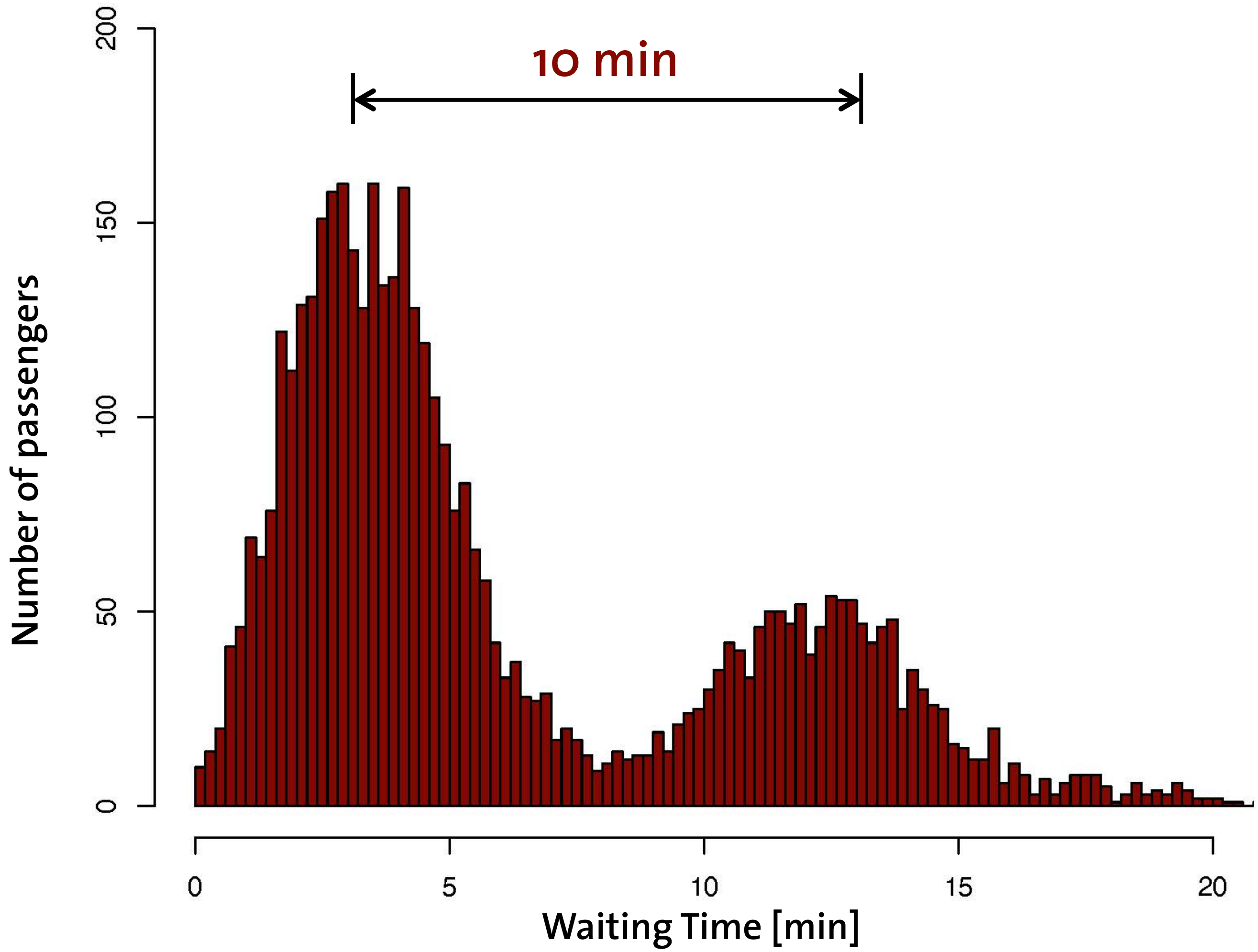


Source: maps.google.com

Singapore extensions: Value of seating

Source: maps.google.com

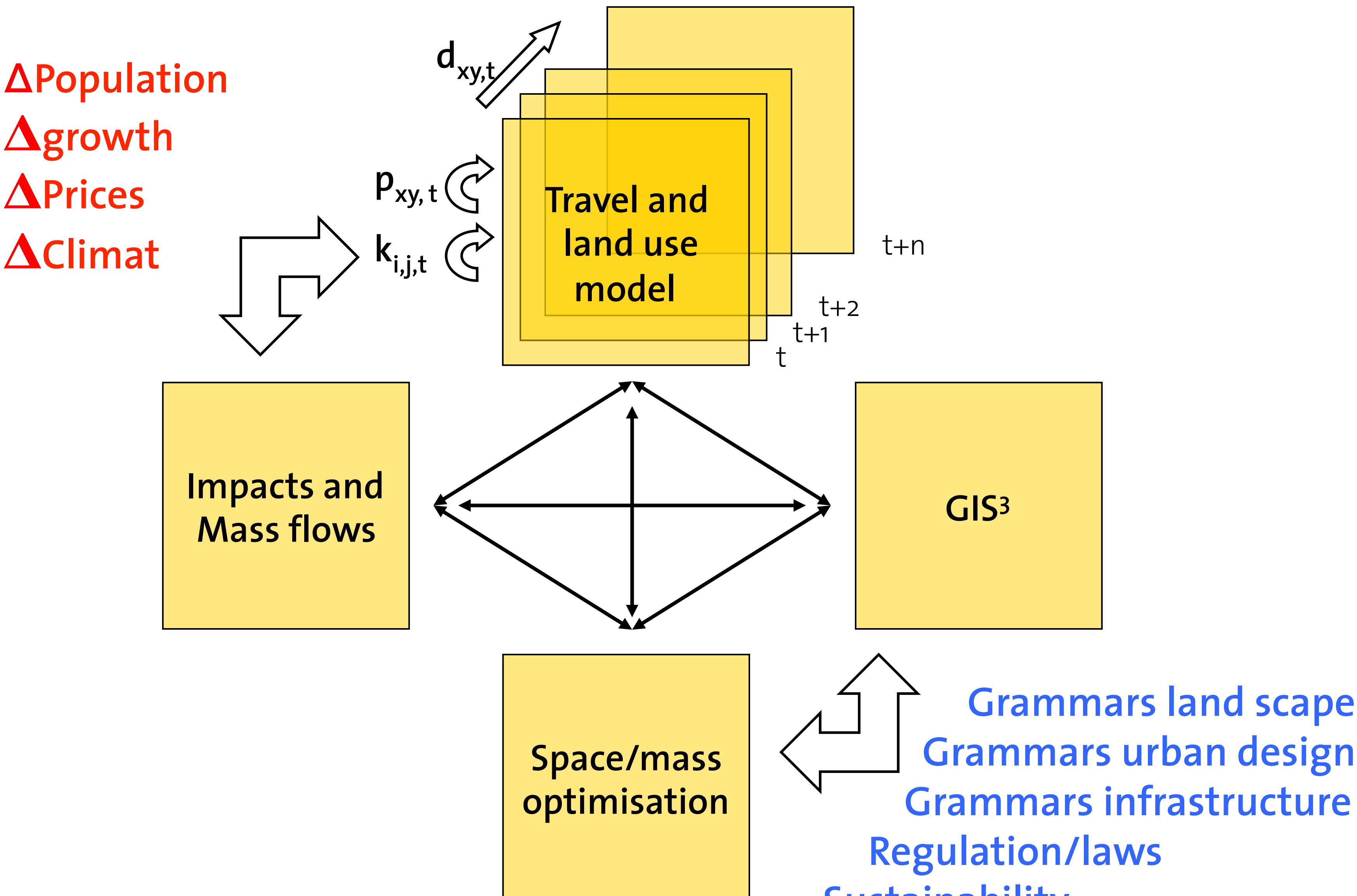
Value of seating: Morning peak EW line at Tampines



High value of a seat (up to 10 min of additional travel time)

Next challenges: Integration of land use (optimisation)

Next challenges: Integration of land use (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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Prof. Kai Nagel
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Manuel Moyo
Kirill Müller
Andreas Neumann
Thomas Nicolai

Benjamin Kickhöfer
Sergio Ordonez
Dr. Bryan Raney
Dr. Marcel Rieser
Dr. Nadine Rieser
Lijun Sun
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Dr. David Strippgen
Michael Van Eggermond
Rashid Waraich
Michael Zilske

Questions ?

www.matsim.org

www.ivt.ethz.ch
www.futurecities.ethz.ch

www.senozon.ch

Hypotheses for travel behaviour