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Agent-based modelling of travel behaviour and flow: The MATSim implementation in Singapore and elsewhere

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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

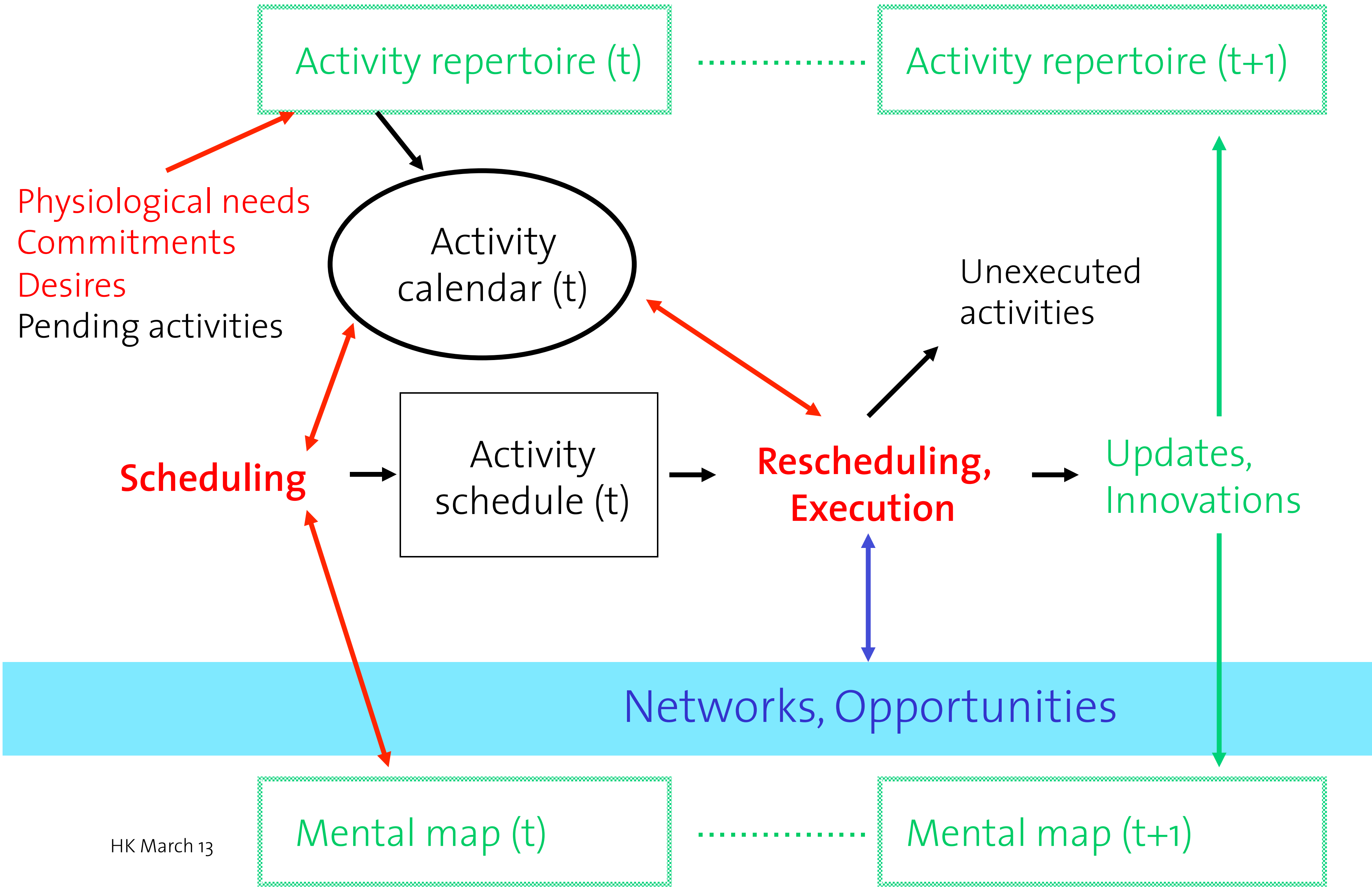
Minimum loads for some of the facilities

“Activity based approach”

Key points of the critique of equilibrium approaches

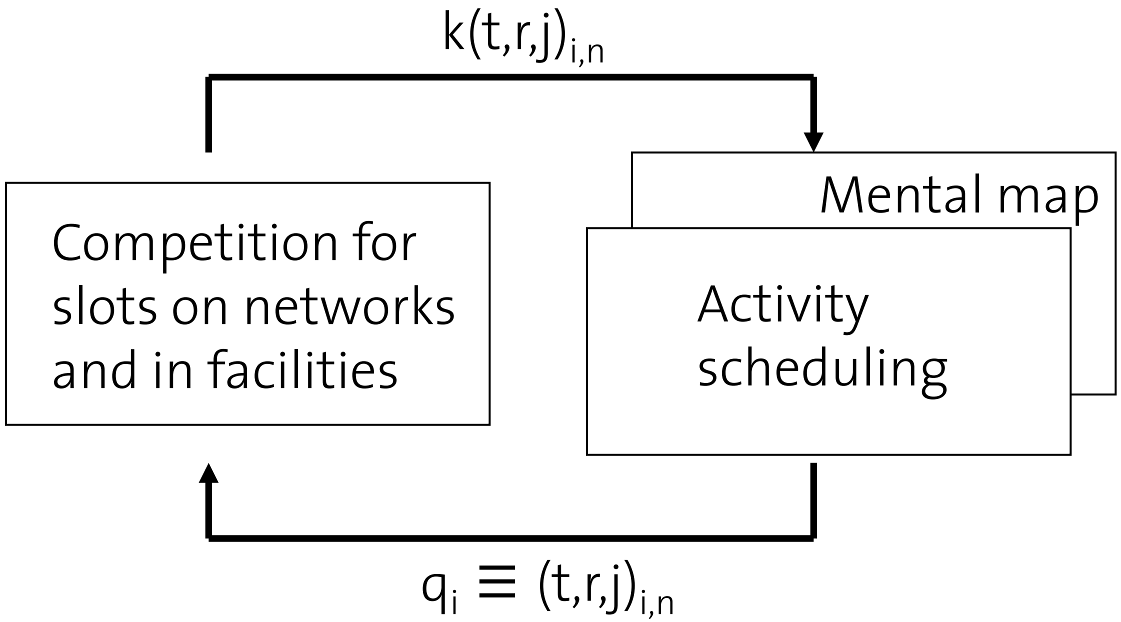
- Travel is derived demand, with some exceptions
- The travellers are constrained by their commitments and tool ownership
- Travellers aren’t in equilibrium
- Travellers don’t know all alternatives
- Travellers don’t plan their whole day (week) in advance

Processes suggested to model personal daily dynamics

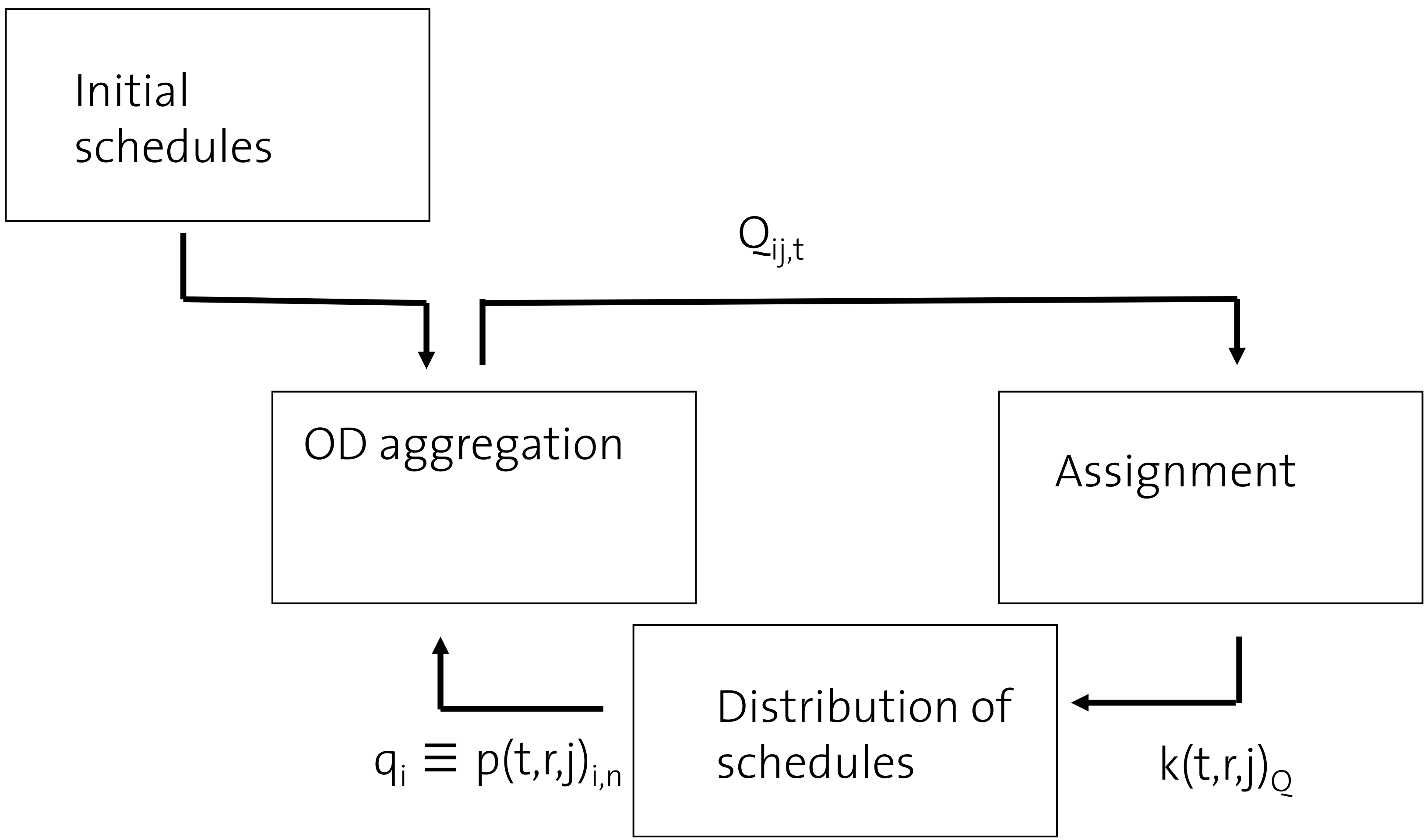


How to find the SUE in an agent-based approach ?

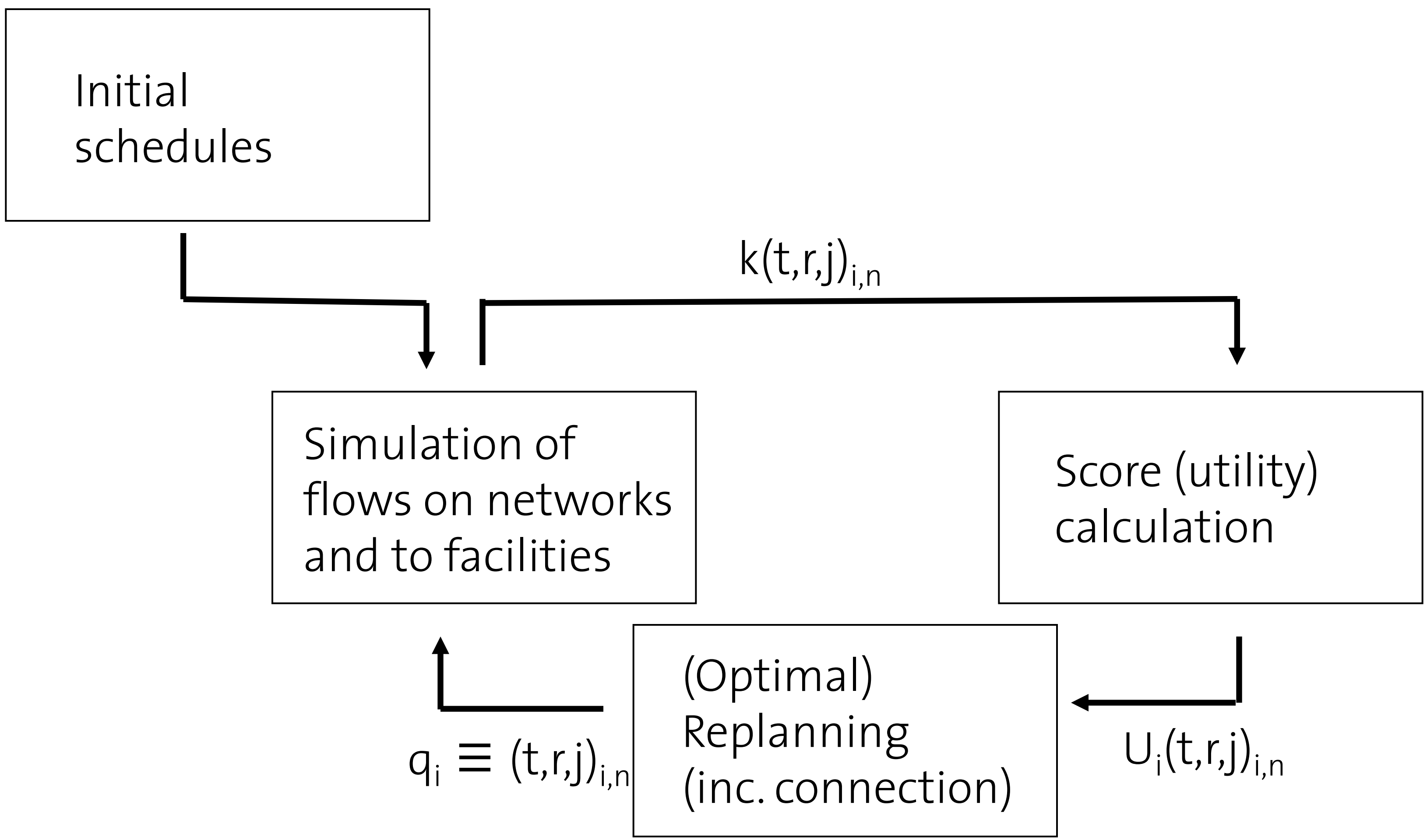
Learning approach of the generic one-day transport model



Equilibrium search in „ABM“ & assignment combinations



Equilibrium search in MATSim



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

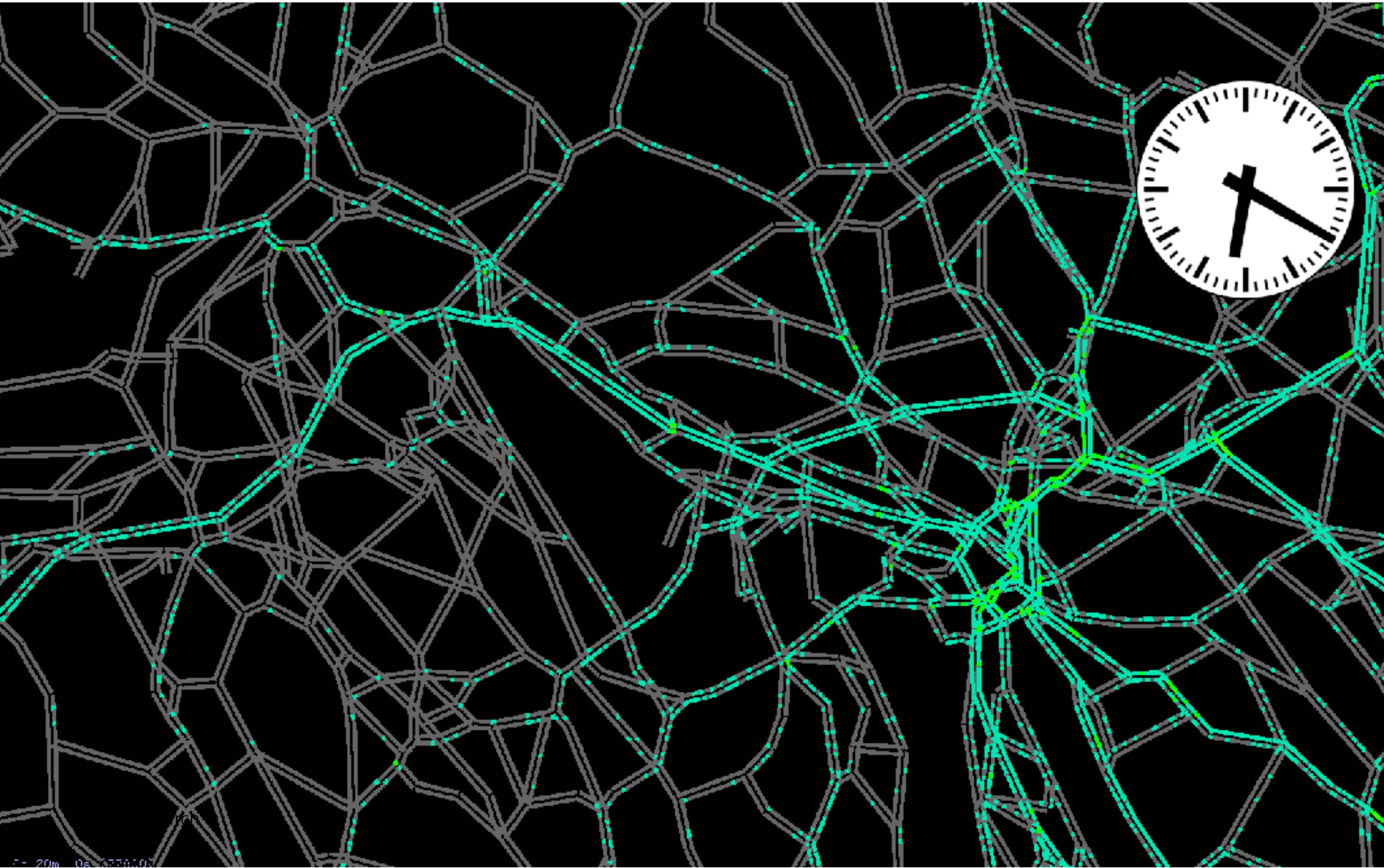
- Code committee
- Regular releases of the code

Known implementations

Location	Scale (agents)	Schedules	DTA	Equi-librium
Switzerland	10^6	MATSim	MATSim	Yes
Berlin	10^6	MATSim	MATSim	Yes
München	10^6	MATSim	MATSim	Yes
Singapore	10^6	MATSim	MATSim	Yes
Gauteng	10^6	MATSim	MATSim	Yes
Cape Town	10^6	MATSim	MATSim	Yes
(Seoul)	10^7	MATSim	MATSim	Yes
(Shanghai)	10^7	MATSim	MATSim	Yes
Tel Aviv	10^6	ABM	MATSim	-
Toronto	10^7	Tasha	MATSim	-
Los Angeles	10^7	CEMDAP	MATSim	-
Netherlands	10^7	Albatross	MATSim	-
Dublin	10^6	-	MATSim	-
(London)	10^7	ABM	MATSim	-

MATSim today

Following the agents



MATSim: Logic of the event-based simulation – Step 1

Initial plan of agent 1:

- Home 8:00
- Leg 0.20 Car Link 1, 2
- Work 8:00
- Leg 0:20 Car Link 2,1
- Home 7:40

Agent 2

- Home 8:00
- Leg 0.20 Car Link 3, 2
- Work 8:00
- Leg 0:20 Car Link 2, 3
- Home 7:40

MATSim: Logic of the event-based simulation – Step 2

List of scheduled events at 8:00

Agent 1 Enter link 1 8:00

Calculate free flow time on link 1 dt = 0.15

Agent 2 Enter link 3 8:00

Calculate free flow time on link 3 dt = 0.16

MATSim: Logic of the event-based simulation – Step 3

List of scheduled events at 8:01

Agent 1	Join queue at end of link 1	8:15
Agent 2	Join queue at end of link 3	8:16

MATSim: Logic of the event-based simulation – Step 4

List of scheduled events at 8:15

Agent 1	Check queue at end of link 1	8:15

Can agent 1 leave the link ?

If yes, add

Agent 1	Leaves link 1	8:15

If no, add

Agent 1	At end of queue	8:16

Agent 2	Join queue at end of link 3	8:16

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**

Activity schedule dimensions

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

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

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

2010 MATSim: Initial demand

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

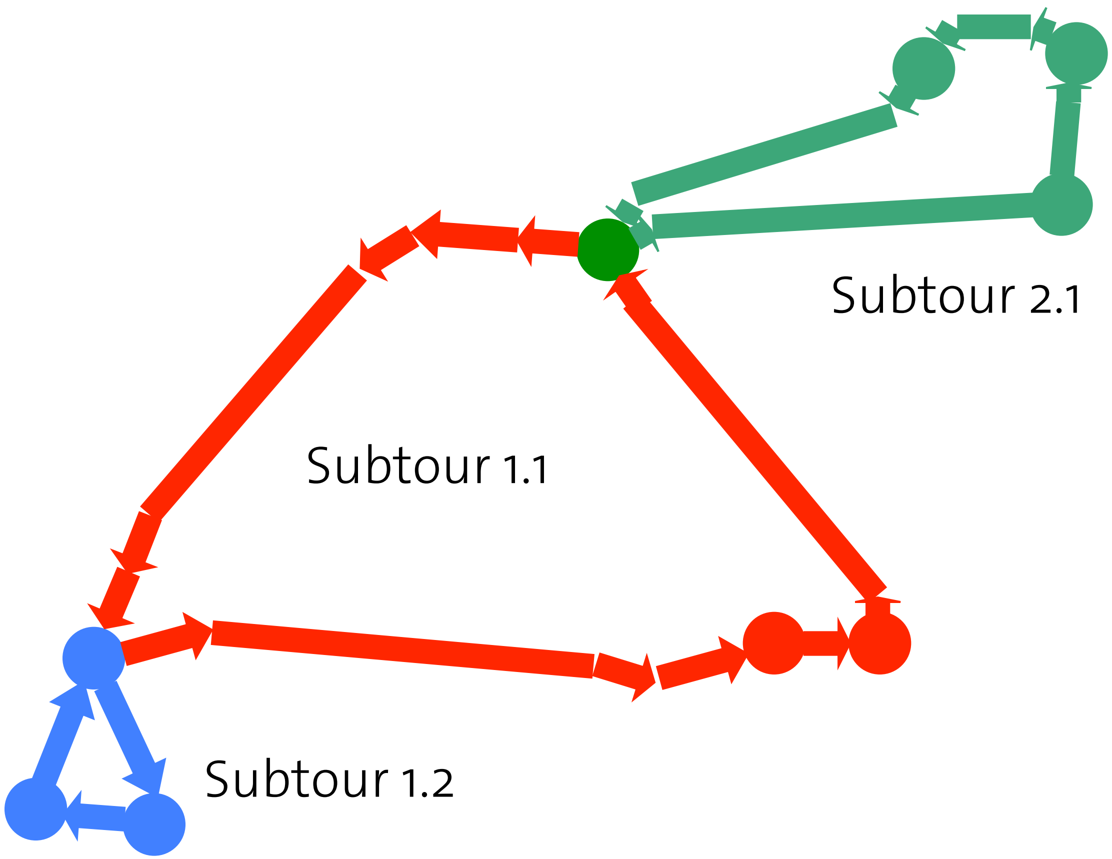
Number, type, sequence and duration of activities:

- Conditional random draw from observed categorised MZ 2000-2005 distributions by person type

- Location of work/school activity:
  - Draws from a (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

Mode choice: Subtour



2010 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

Modelling Switzerland 2009

2009 MATSim Switzerland: Configuration

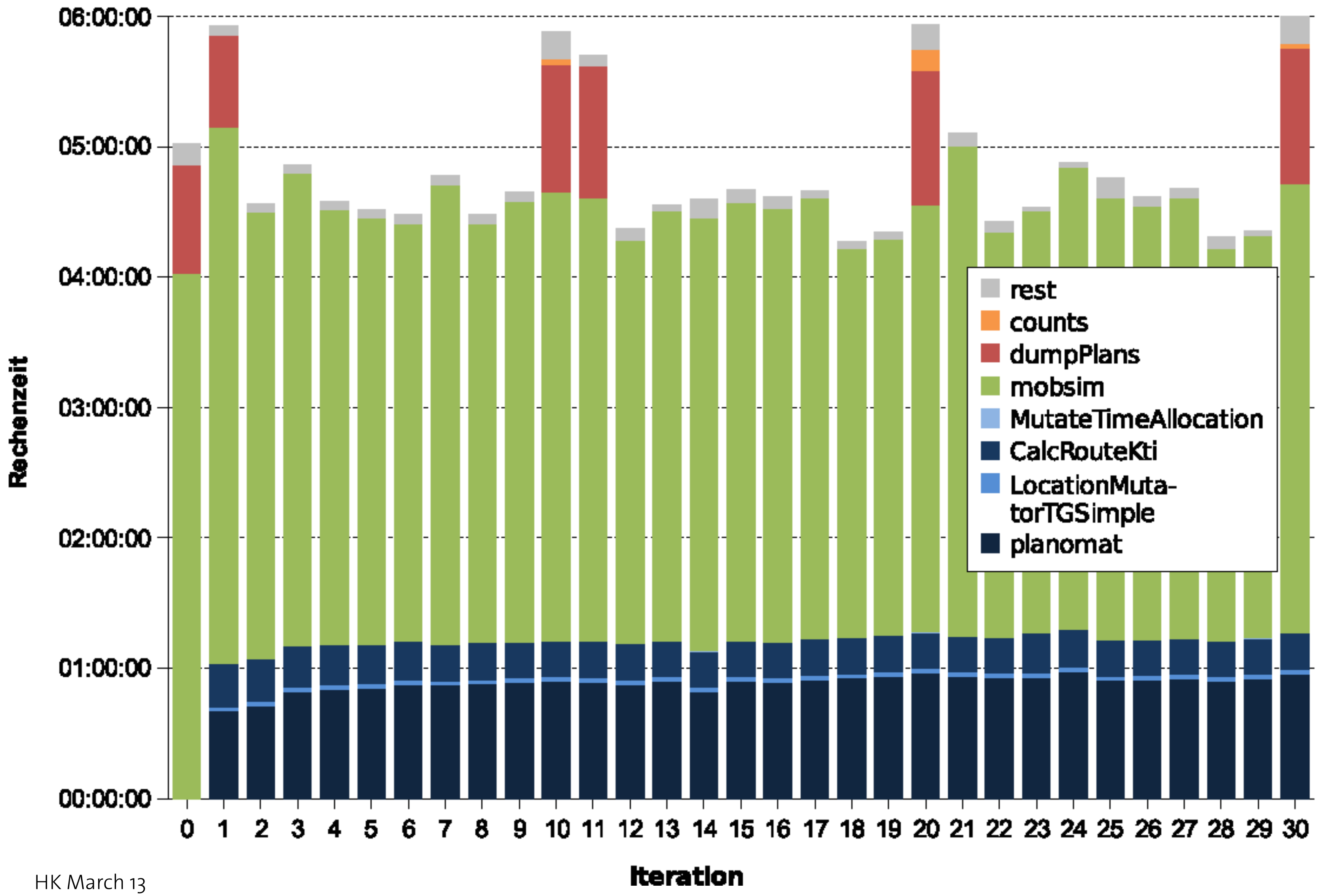
During the iterations:

- 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:

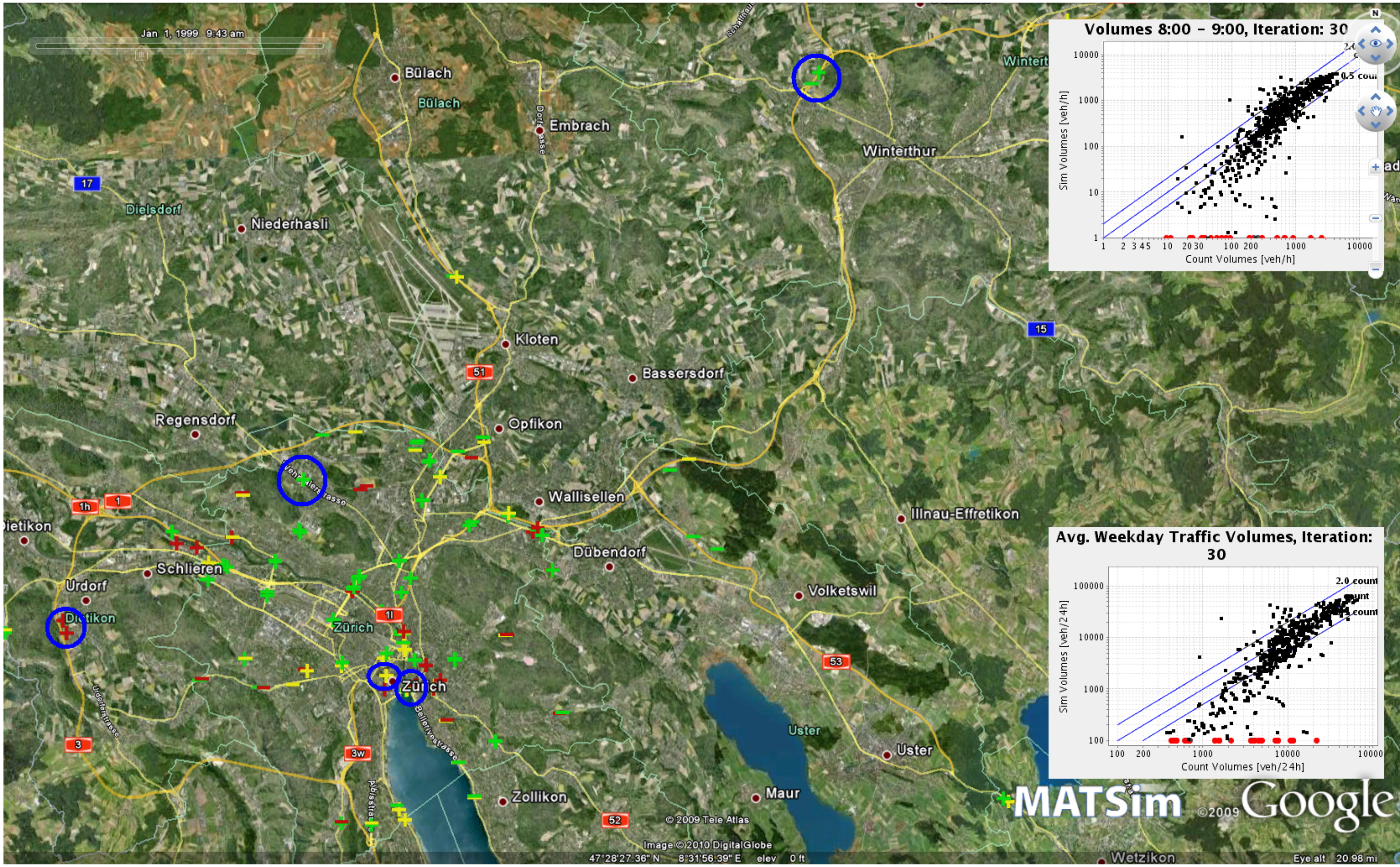
- $6.0 * 10^6$ agents with 11 activity types
- $1.6 * 10^6$ facilities
- $0.8 * 10^6$ links
- 24 * 60 * 60 seconds

2009 MATSim Switzerland: Computing time

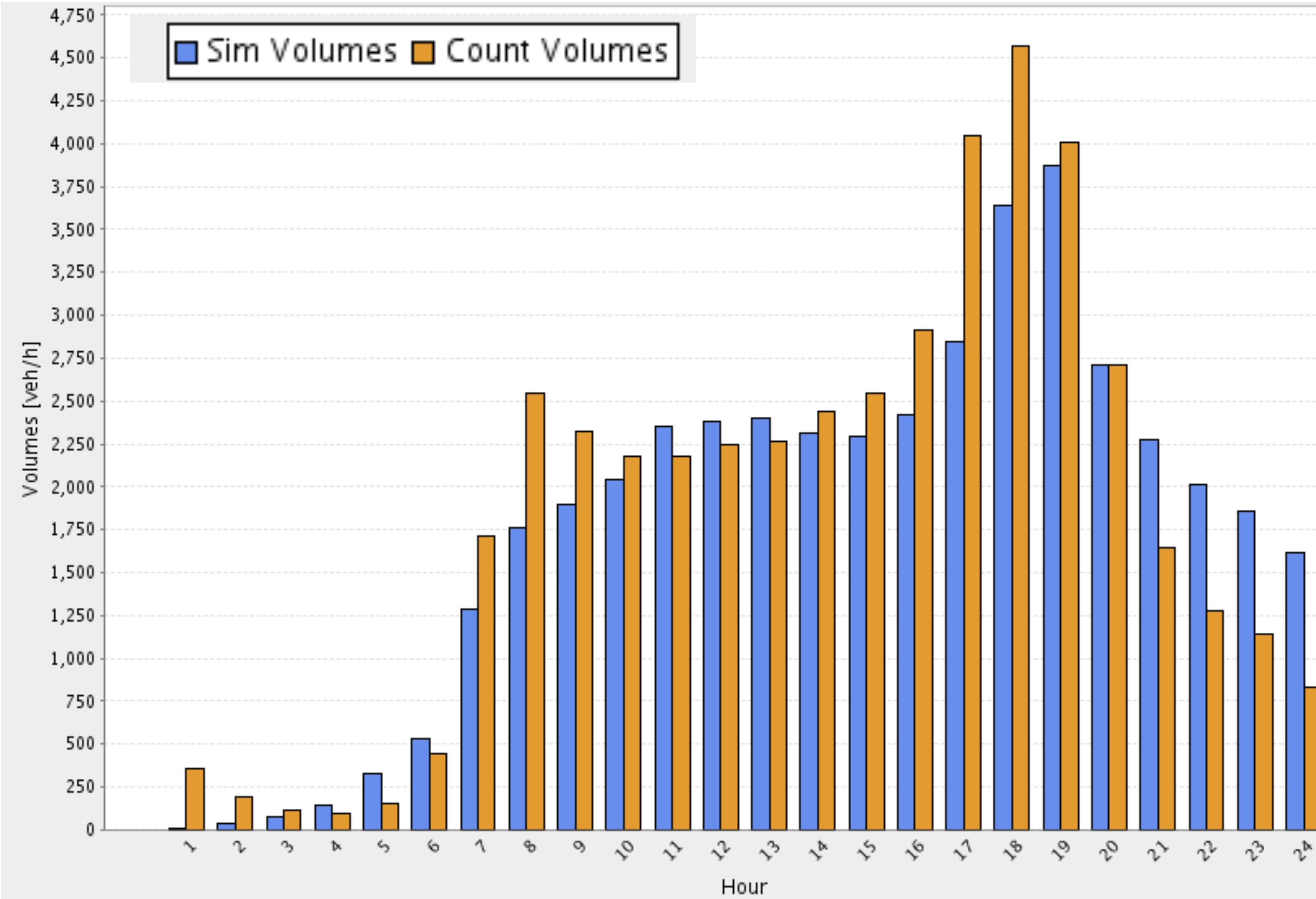


Balmer, 2009

Quality of the results: Overall counts



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



Current progress: Berlin

Network: 113 000 links

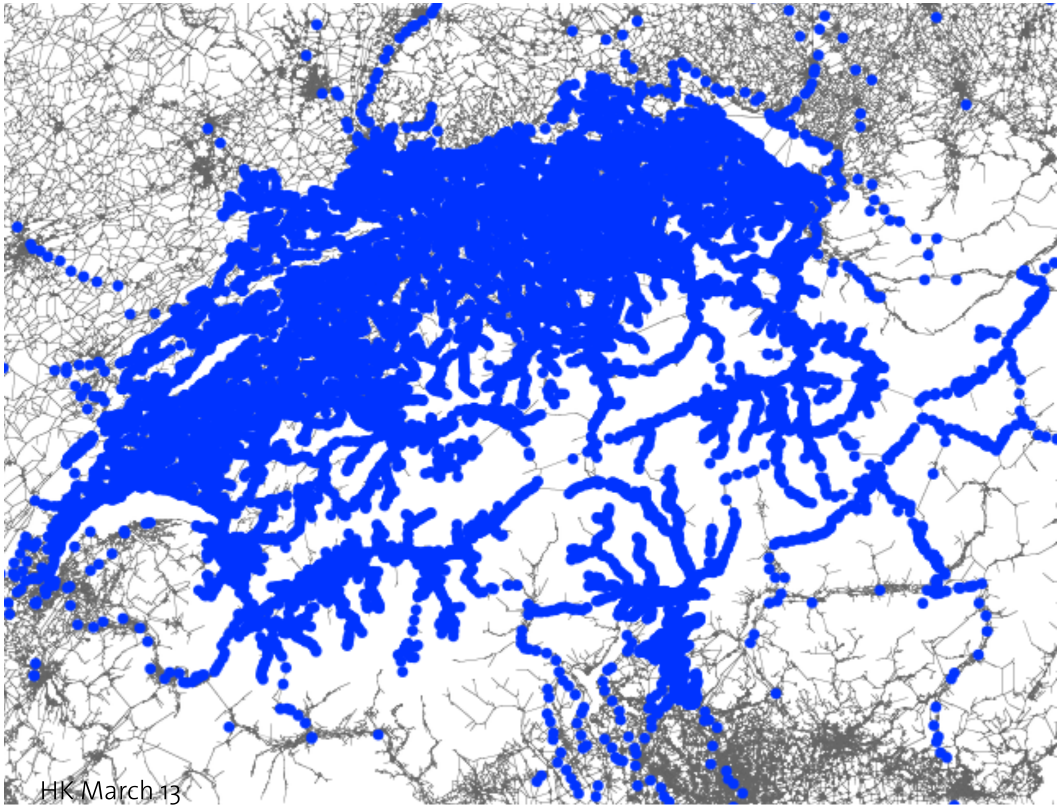
Population: 4,5 million agents

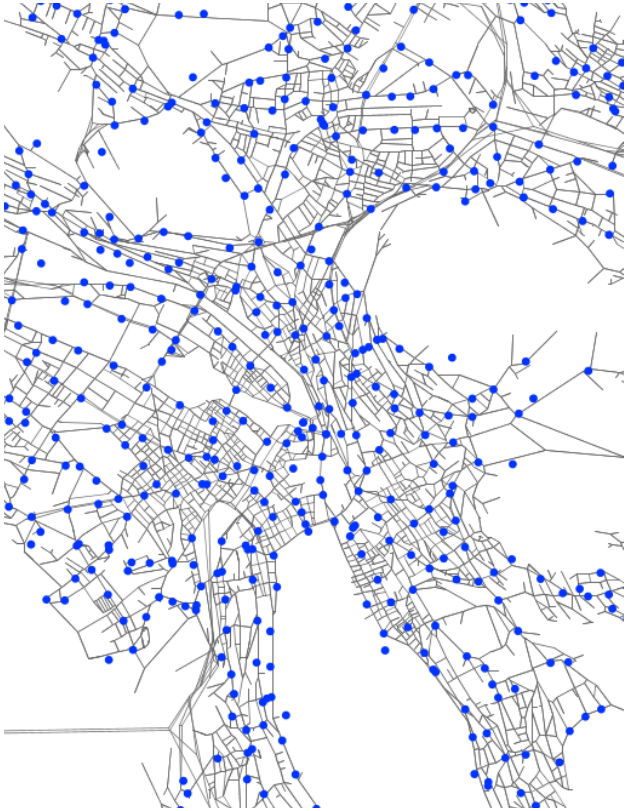
Public Transport: 530 lines, 96 transit vehicle types

Mode choice, Departure time choice, Route choice (car + transit)

Current progress: Switzerland

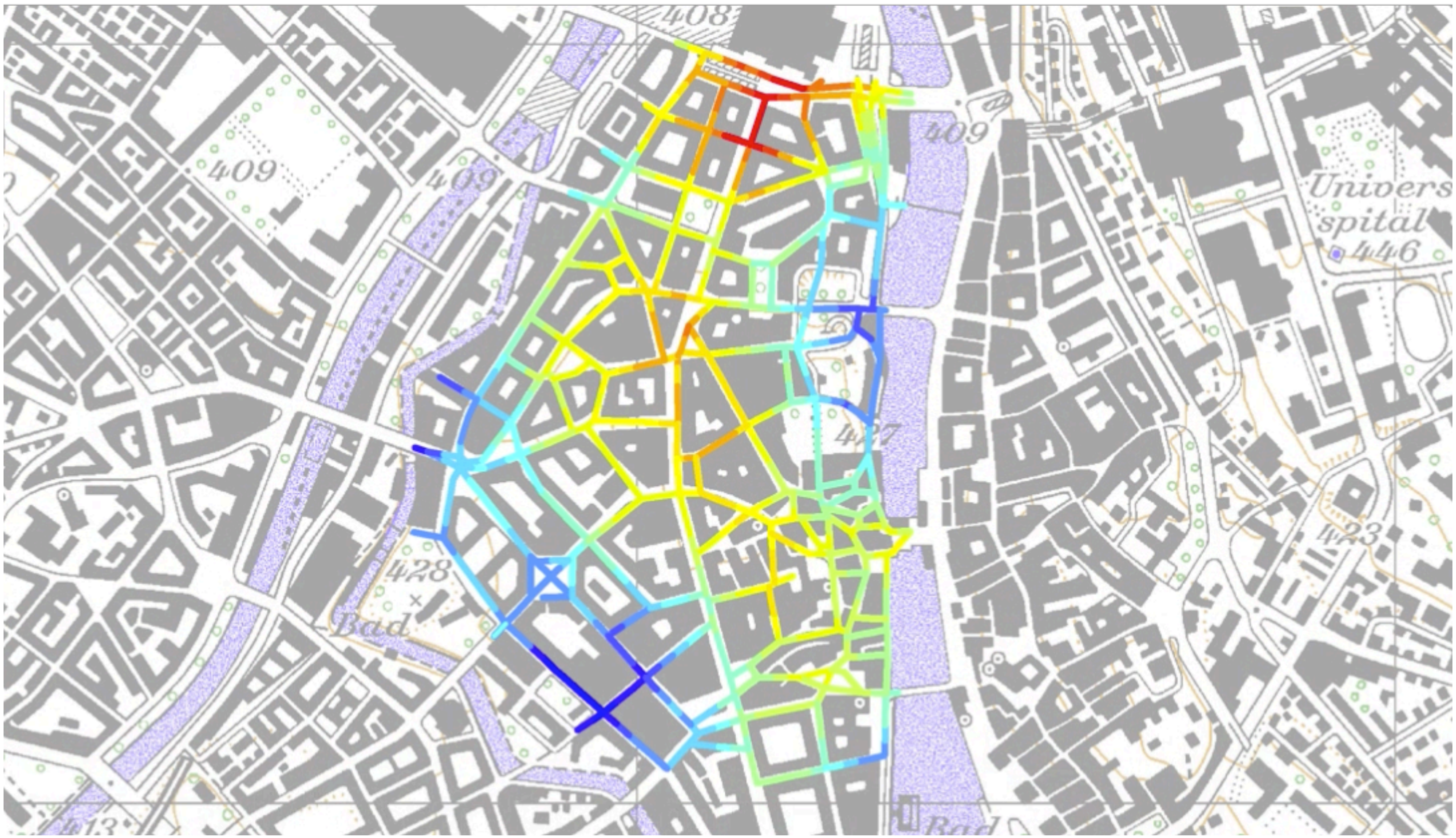
Network: ~ 1 million links (navigation network)
Population: 8 million
Complete public transport (all trains, buses, trams, cablecars, ...)
Mode choice, Departure time choice, Route choice (car + transit)





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

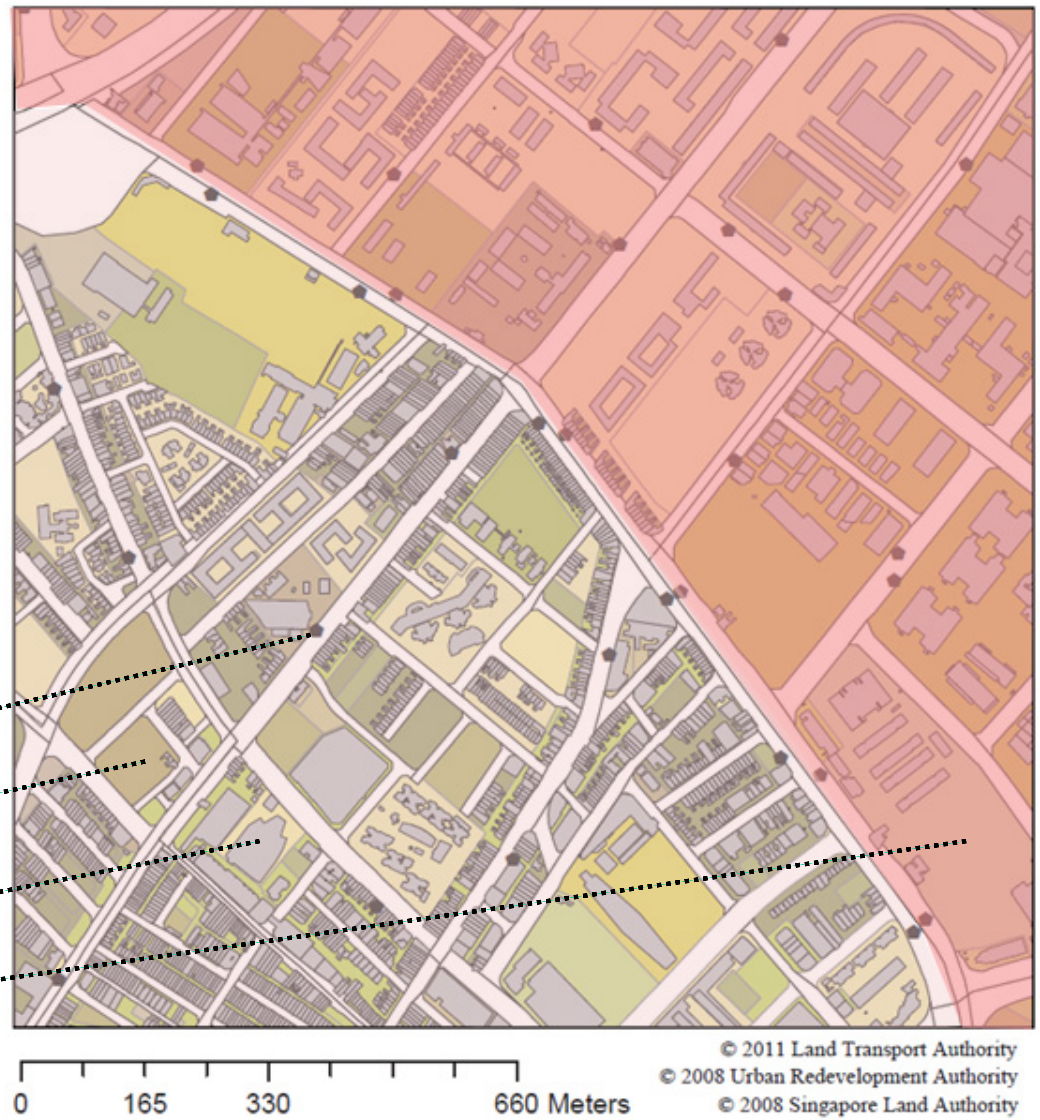
Work location model: motivation and idea

Background:

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

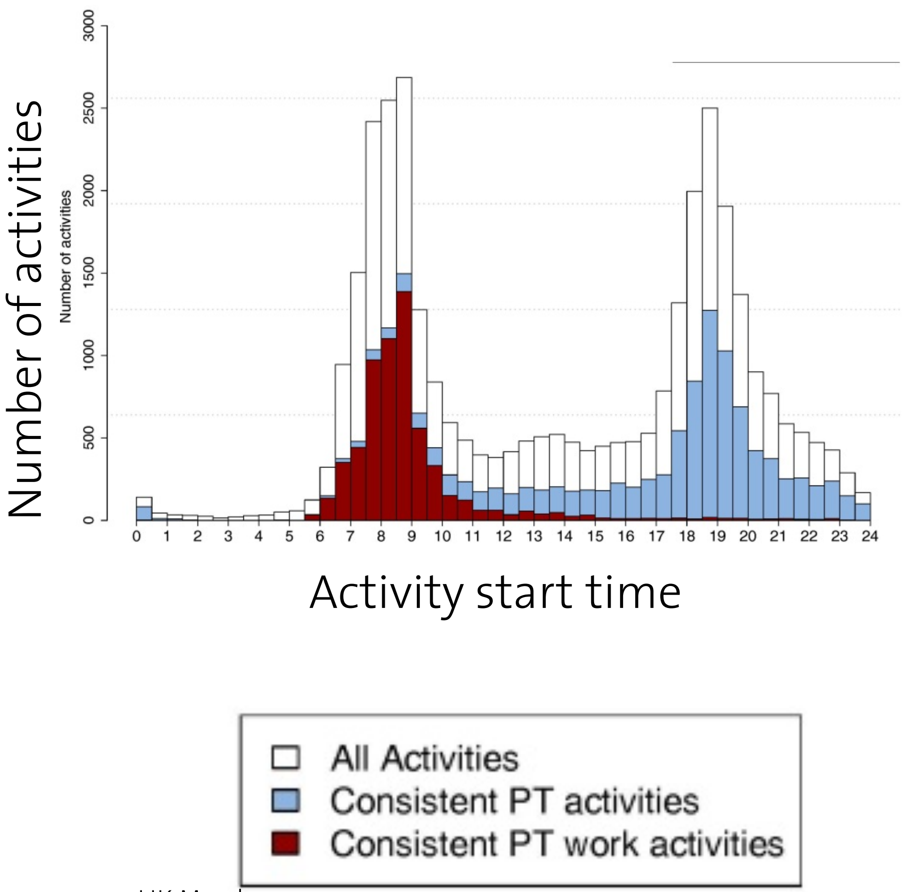
Combination of various data sources:

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

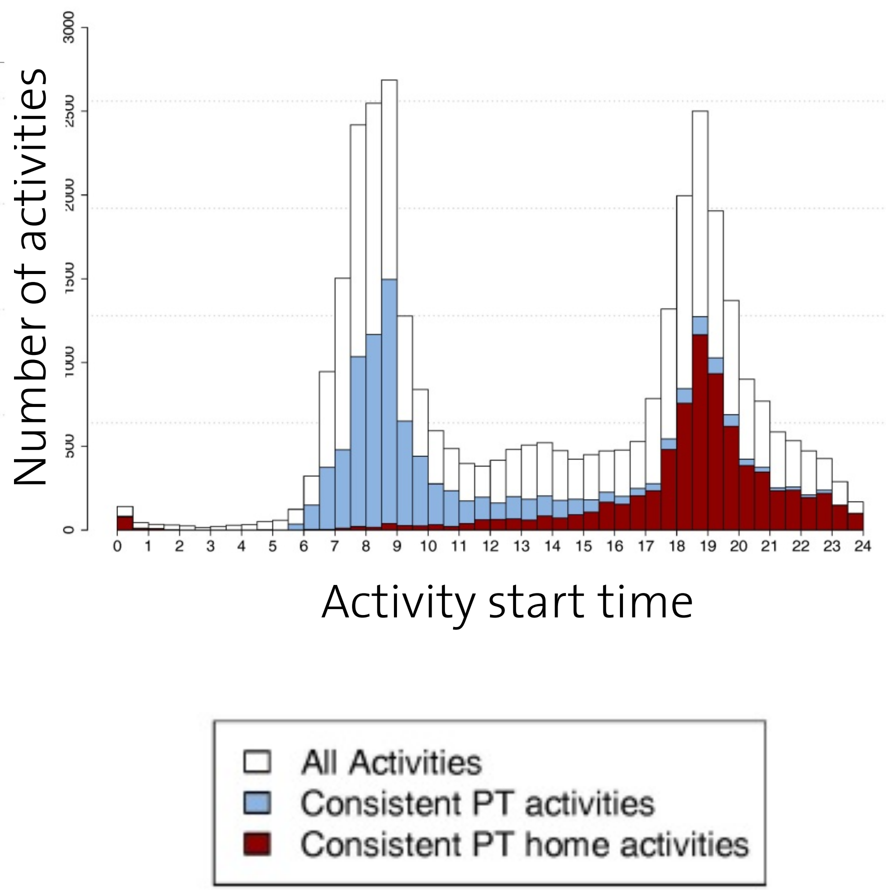


Detection of work activities: start time

Work activities

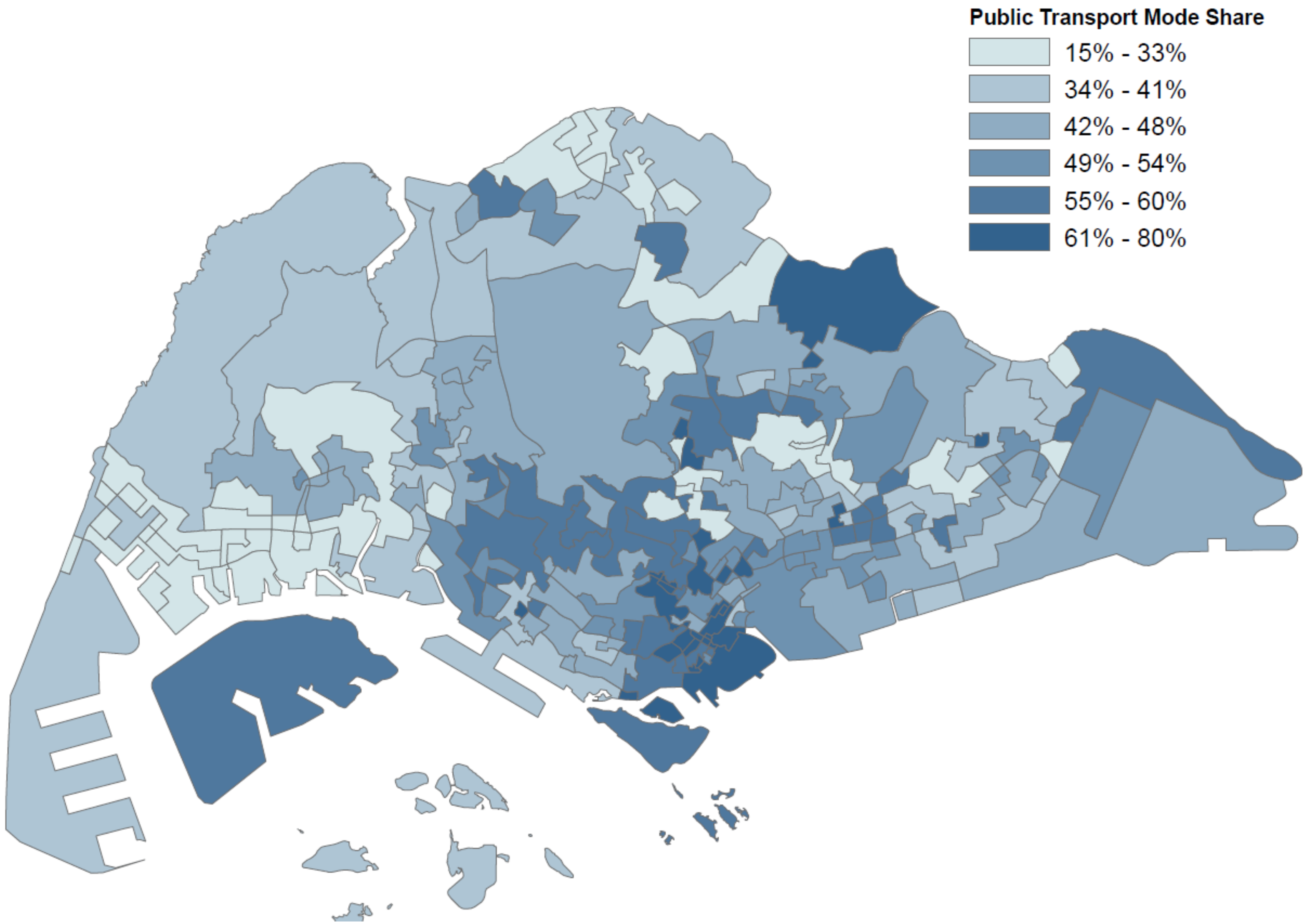


Home activities

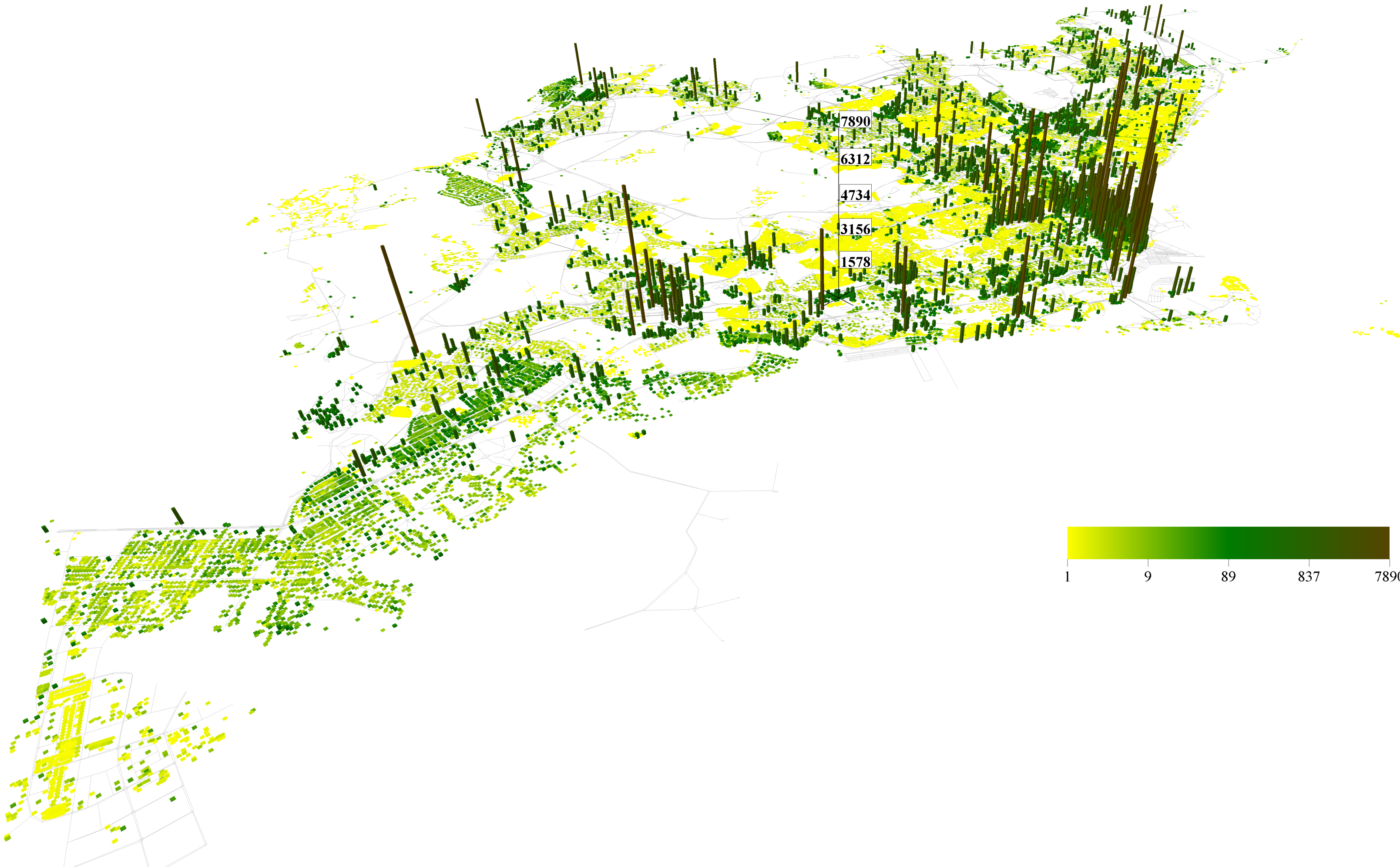


Applying to public transport smart card records

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

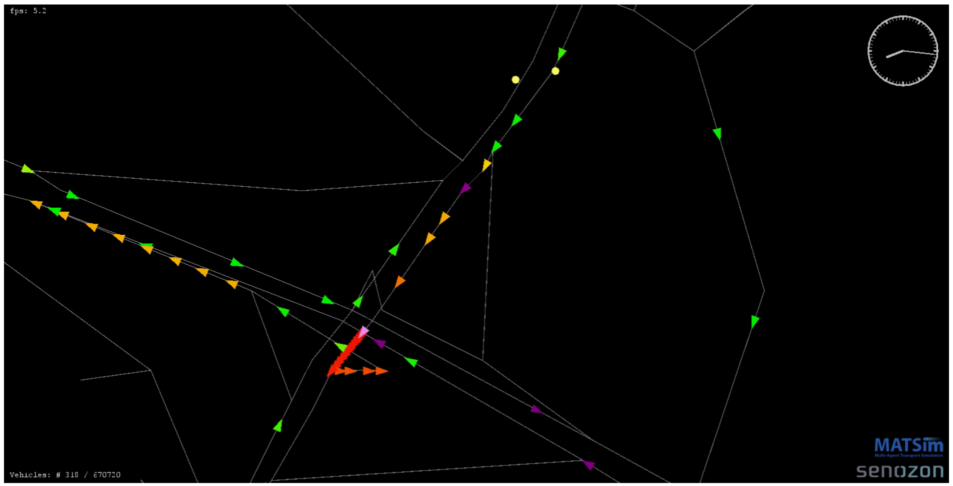
Singapore extensions: Interaction between car and buses

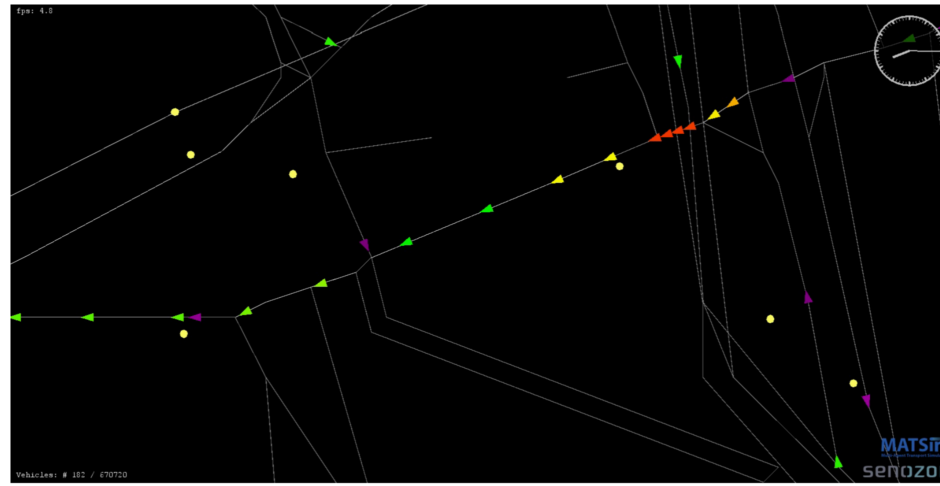
Source: maps.google.com

Interaction between car and buses (purple)

Without buslane:
Adam Rd / PIE

With buslane:
Gelyang Rd, aft Sims Way





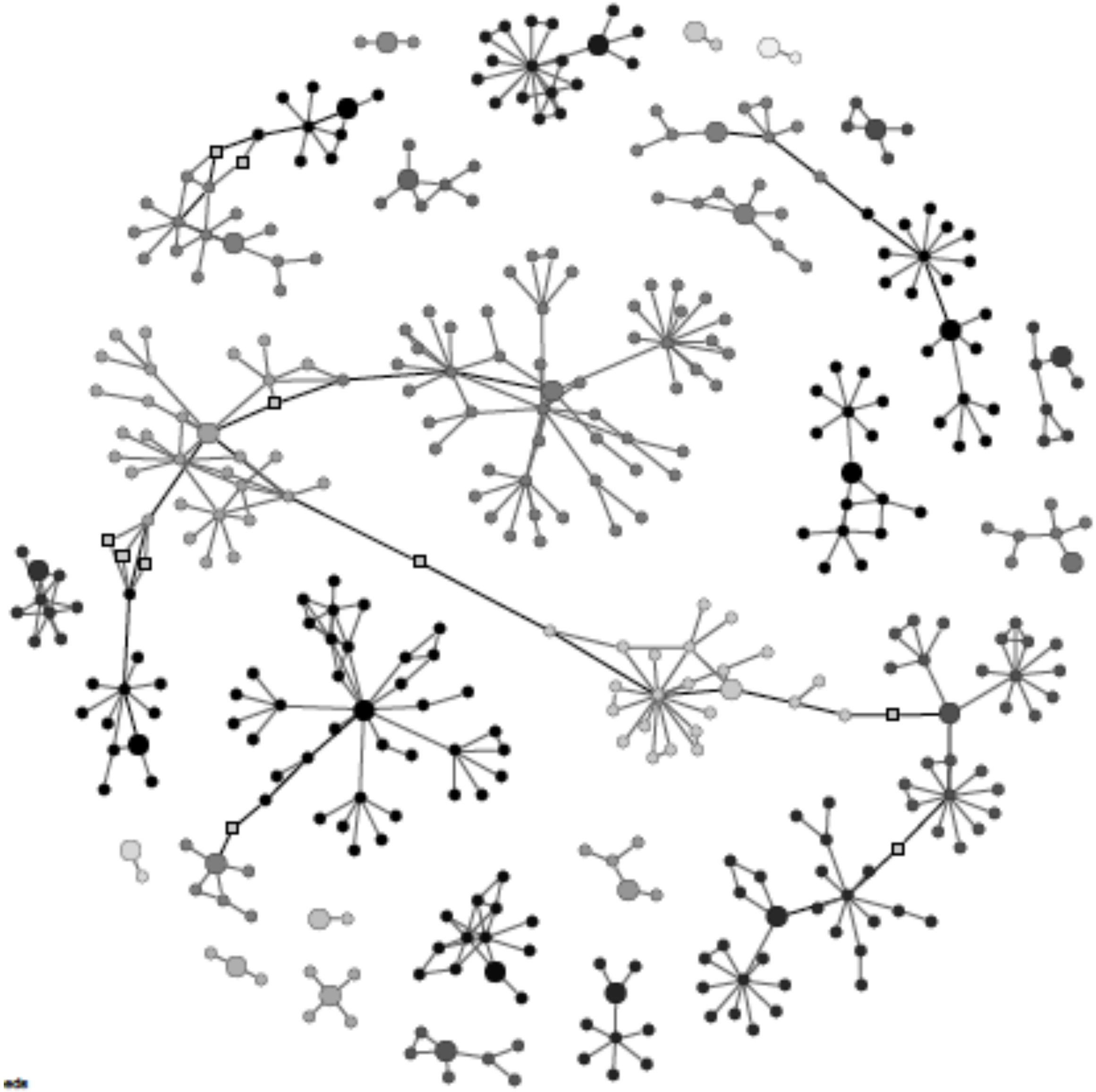
Source: maps.google.com

Simulation of public transport supply in Singapore

Video available at http://vimeo.com/37719740

Next challenge: Social networks

Next challenge: Social networks



Next challenge: Social network imputation

Data needs:

- Snowball samples
- Phone/SMS-based networks
- (email based networks)

Population synthesis:

- Model definition and estimation (e.g. ERGM, Arentze et al.)
- Scale
- Validation data

Next challenge: Social network informed models

Data needs:

- Diaries with social contact information
- Information acquisition diary
- Expenditure allocation surveys

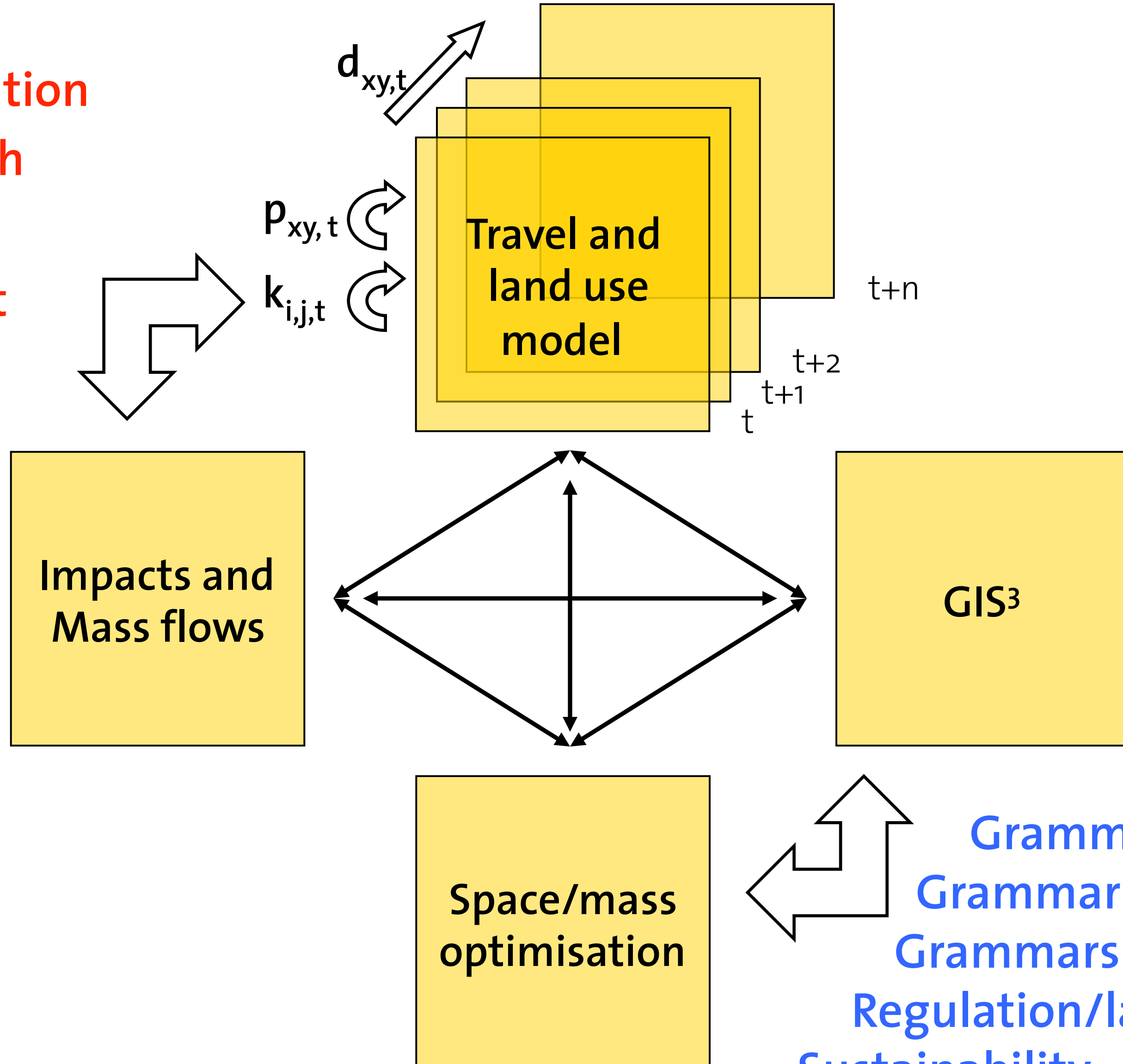
Choice models:

- Location choice
- Resource sharing (vehicles, tasks) (in households, groups)

Next challenges: Integration of land use (optimisation)

Next challenges: Integration of land use (optimisation)

ΔPopulation
Δgrowth
ΔPrices
ΔClimat



Grammars land scape
Grammars urban design
Grammars infrastructure
Regulation/laws
Sustainability

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
Andreas Horni
Johannes Illenberger
Dr. Gregor Lämmel
Nicolas Lefebvre
Prof. Kai Nagel
Dr. Konrad Meister
Manuel Moyo
Kirill Müller
Andreas Neumann
Thomas Nicolai

Benjamin Kickhöfer
Sergio Ordonez
Dr. Bryan Raney
Dr. Marcel Rieser
Dr. Nadine Rieser
Lijun Sun
Alexander Stahel
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