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.

Agent-based modelling for transport planning

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Basic assumptions for transport planning

Basic definitions

Social generalised costs is the sum of

individual generalised costs, i.e.

decison relevant generalised costs &

overlooked individual costs

And the

externalities caused

Basic assumption 1

Accessibility ~

Opportunities,

Speeds

Basic assumption 2

Traffic is a system of moving, self-organising

Queues

Basic assumption 3

The crucial short-term interaction between capacity, i.e. the

number of *slots*

for the desired speed and the

current demand

Basic assumption 4

Societies chose their

number of *slots*

By the

design/operation of the road/rail/bike network

For the

desired speeds

Basic assumption 5

Travel demand (pkm or tkm) is a

normal good

i.e. it grows with

decreasing individual “generalised costs”

Basic assumption 6

Decision relevant generalised costs are the

sum of the risk and comfort weighted

monetary expenditure and the

time spent

Basic assumption 7

The travellers chose their

average decision relevant generalised costs

with their package of

locations (residence, work) and **mobility tools**

Basic assumption 8

A person‘s travel demand is the

result of its out-of-home activity participation

constrained by the currently

available time and money resources and
their chosen average generalised costs

Basic assumption 9

A person‘s travel experience is the result of the

queues (joined or avoided)

And can be addressed by

mostly costly changes

How do we label our models?

A terminological problem ?

Resolution	Agents, flows
Scheduling model	Trip, tour, daily chain (with breaks)
Choice model	DCM, rules&heuristics
Route choice	Integrated, external (with consistent valuations?)
Choice set construction	Explicit, implicit
Solution method	Whole population (& MSA or similar) Sample enumeration (& MSA or similar), co-evolutionary search
Schedule equilibrium	Yes, no

The typical four-stage model

Resolution	Agents**, flows**
Scheduling model	**Trip, tour**, daily chain (with breaks)
Choice model	**DCM,** rules&heuristics
Route choice	Integrated, **external without consistent valuations**
Choice set construction	**Explicit**, implicit
Solution method	**Whole population** (& MSA or similar) Sample enumeration (& MSA or similar), co-evolutionary search
Schedule equilibrium	**(Yes)**, no

The typical activity-based model (ABM)

Resolution	**Agents**, flows
Scheduling model	Trip, tour, **daily chain** (with breaks)
Choice model	**DCM** , rules&heuristics
Route choice	Integrated, **external without consistent valuations**
Choice set construction	**Explicit**, implicit
Solution method	Whole population (& MSA or similar) **Sample enumeration** (& MSA or similar), co-evolutionary search
Schedule equilibrium	Yes, **none reported it yet**

MATSim

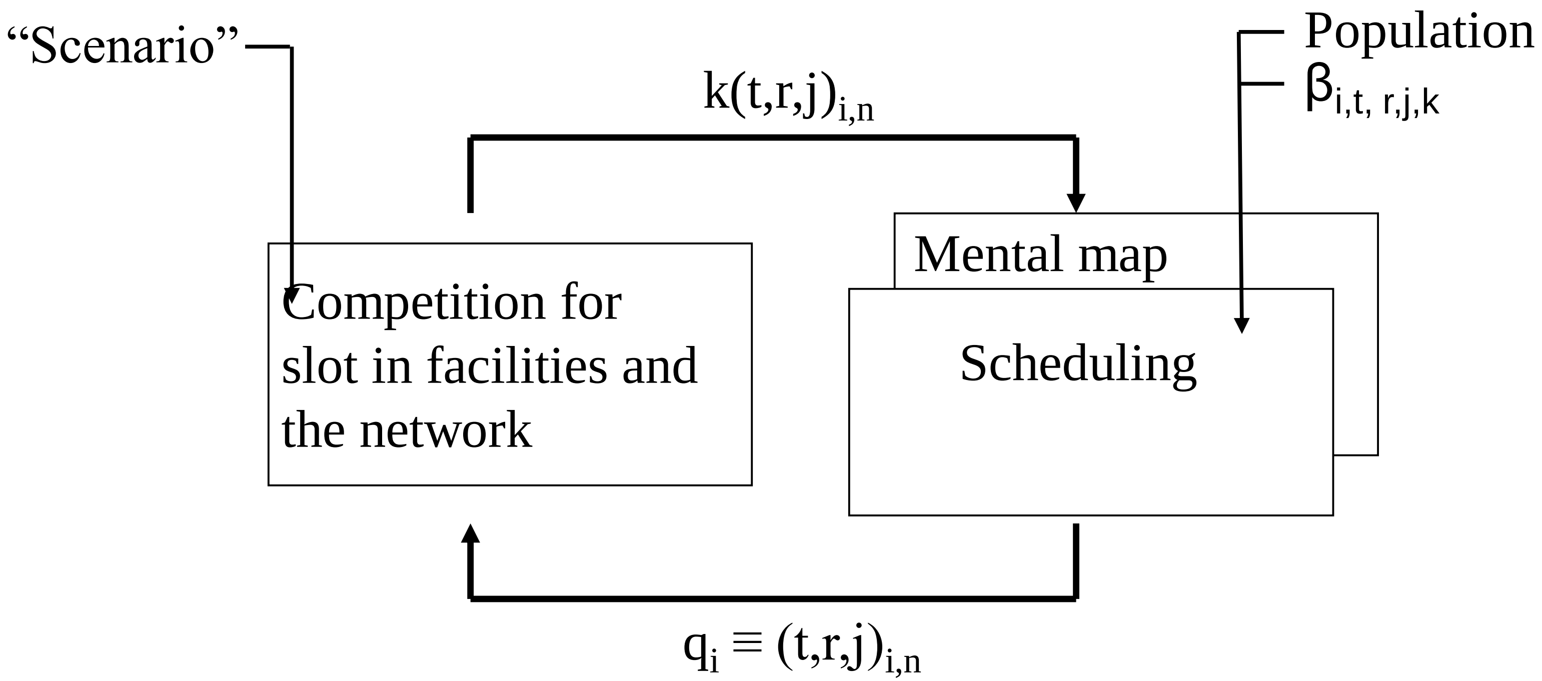
Resolution	**Agents**, flows
Scheduling model	Trip, tour, **daily chain** without breaks
Choice model	**DCM** and/or **rules**&heuristics
Route choice	**Integrated with consistent valuations**, external
Choice set construction	Explicit, **implicit**
Solution method	Whole population (& MSA or similar) Sample enumeration (& MSA or similar), **co-evolutionary search**
Schedule equilibrium	**Yes**, no

What is the task ?

Time horizon of transport planning

	System	Person
Long term	*slots* Regulation	Home and work locations Mobility tool ownership Social networks
Medium term	Services Prices Awareness	Season tickets
Short term	Operations	**Scheduling**

Generic model structure



Market model

For all goods i of the market:

$$k'_{i,togz} \quad = \quad f(q'_{i,togz}\,(k'_{i,toqz}, B_{ogz}), A_{i,togz})$$

k'	:	Estimated generalised costs [SFr/good]
q'	:	Estimated demand [Elements/Unit time]
A	:	Supply of the goods
B	:	Population (natural and legal)

t	:	Time t
o	:	Place o
g	:	Group g
z	:	Year z

Key points of the critique of equilibrium approaches

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

MATSim – A GNU open source project

MATSim: A GNU public licence software project

Main partners:

- TU Berlin (Prof. Nagel)
- ETH Zürich & FCL Singapore
- Senozon, Zürich (Dr. Balmer)
- Simunto, Zürich (Dr. Rieser)

Contributors, users, e.g.:

- TU Poznan
- University of Pretoria
- SBB, Bern

- Systems Group, DINF, ETH Zürich

2018 status

Trondheim
Germany
Amsterdam
Stockholm
Rotterdam
Hamburg-Wilhelmsburg
London
Berlin
Dublin
Poznan
Brussels
Cottbus
Belgium
Munich
Austria
Paris
Sochi
Stuttgart
Vorarlberg
Zurich
Barcelona
Switzerland
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İzmir
Tel Aviv
Samara City
Seattle
Sioux Falls
Toronto
New York City
San Francisco Bay Area
Los Angeles
Tampa
Caracas
Quito
Joinville
Santiago
Ivory Coast
Lagos
Gauteng
South Africa (freight only)
eThekwini
Cape Town
Nelson Mandela Bay
Baoding
Seoul
Tokyo
Yokohama
Kyoto
Shanghai
Patna
Cagayan de Oro City
Singapore
Padang
Jakarta
Perth
Yarrawonga, Mulwala
Melbourne
Auckland

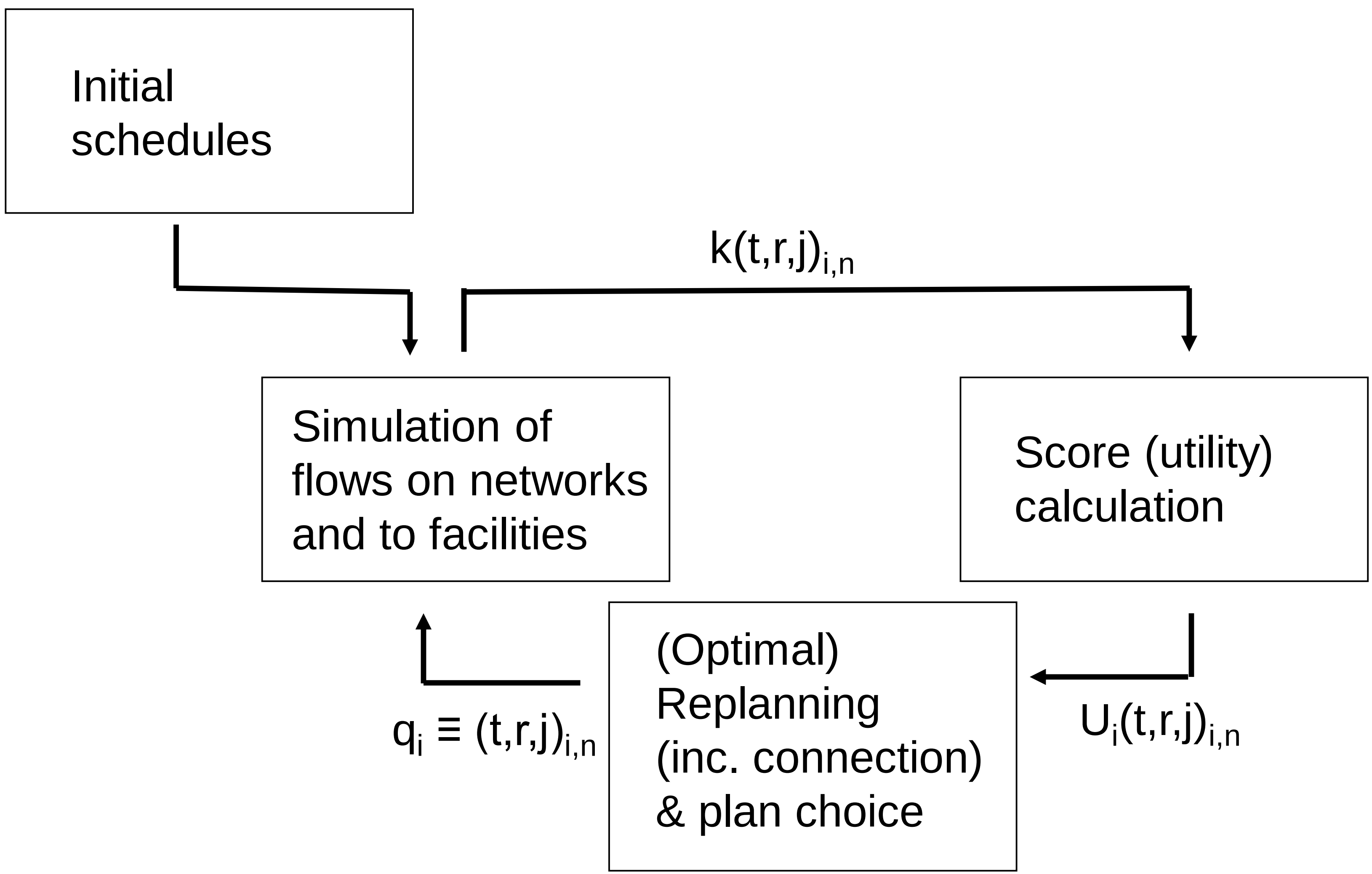
Current status

Known implementations:	About 45
Research groups:	About 35 (including some beyond transport)
Uses:	Research Some initial commercial uses Some policy consulting
Software:	Last reimplementation in 2012/13 Stable API Daily tests JAVA

Current progress: Singapore

MATSim: Base approach

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

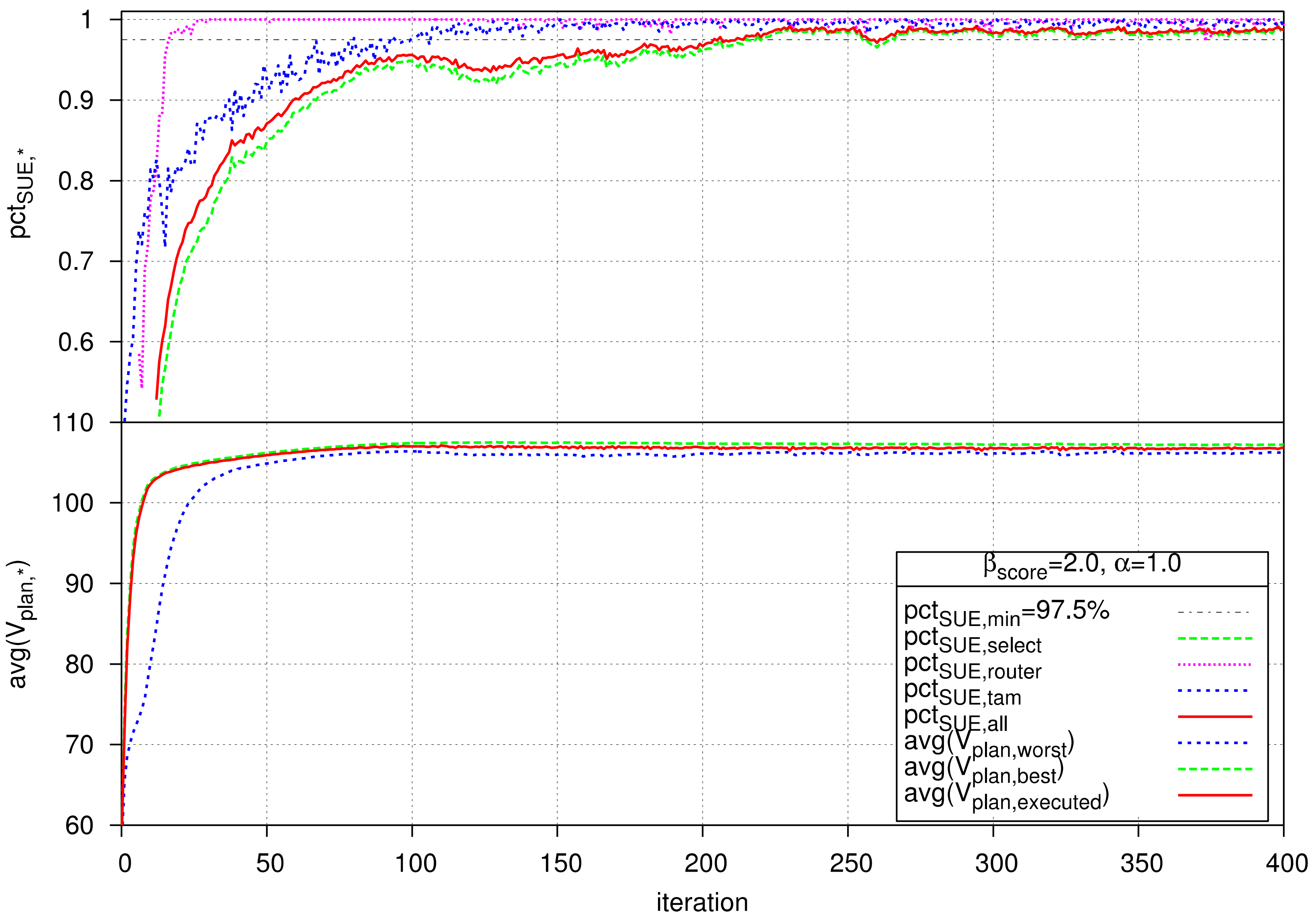
~~Plan 3.1~~	~~H-W-H; 8:00, 17:00; C,C;~~		~~45~~
Plan 3.2	H-W-H; 8:15, 17:30; C,C;		60
Plan 3.3	H-W-H; 7:30, 17:15; B,B	**New**	

(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**

SUE search example



Co-evolution – Issues

- Size of search space ~ Behavioural alternatives
- Rate of replanning (~ MSA)
- Size of the choice set ~ RAM
- Similarity of the daily schedules
- Integration into a log-sum term

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

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

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

Future whole day utility function?

Time elements	linear
• Travel time	By mode and type of service;
	by crowding level
	by comfort level (parking search, stop&go)
• Transfer penalty	
• Late penalty	by activity type
Activity time	log (Vickrey) or S-shape (Joh) (all, individual)
• Minimum duration	by activity type
• Preferred duration	by activity type
• Duration	by time of day (might go away if participation is included)
Destination	Attractiveness, Value for money (on-line, off-line)
Expenditure	by activity
	by mode/type of service

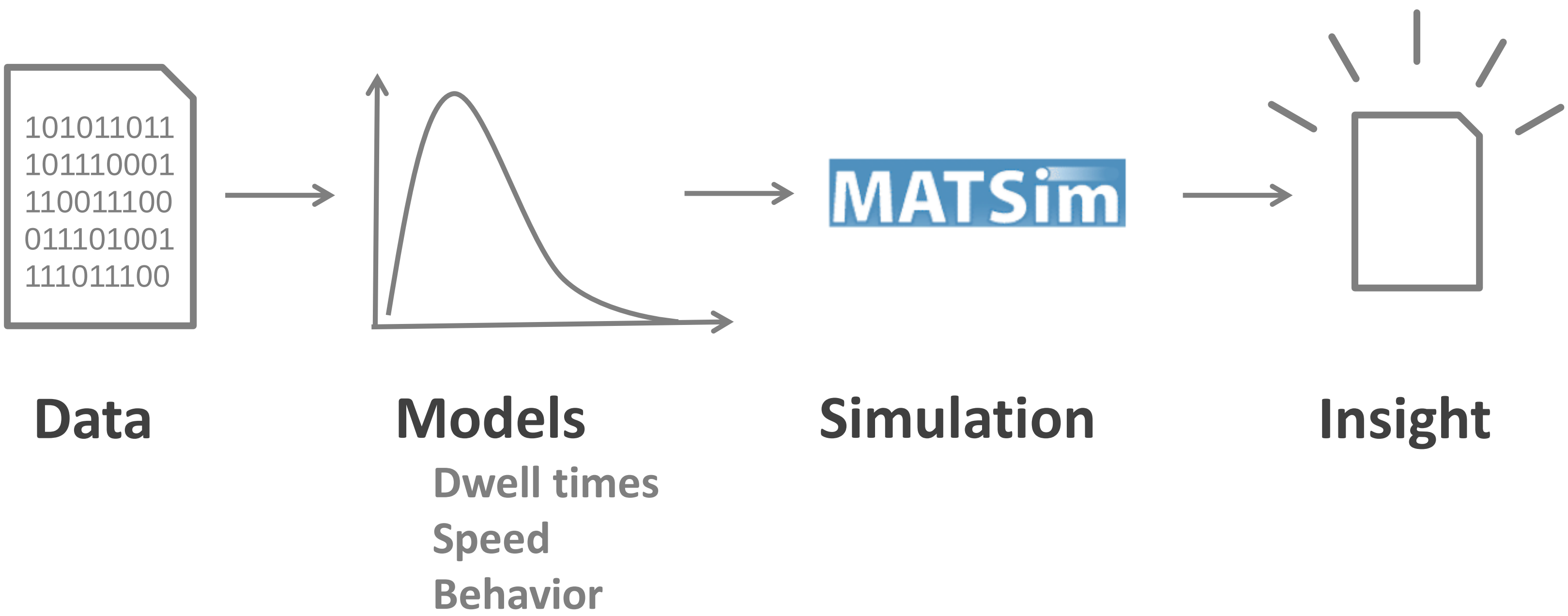
Schedule detail possibilities (in current stable MATSim)

Number and type of activities **(Balac)**
Sequence of activities **(Ordonez)**

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

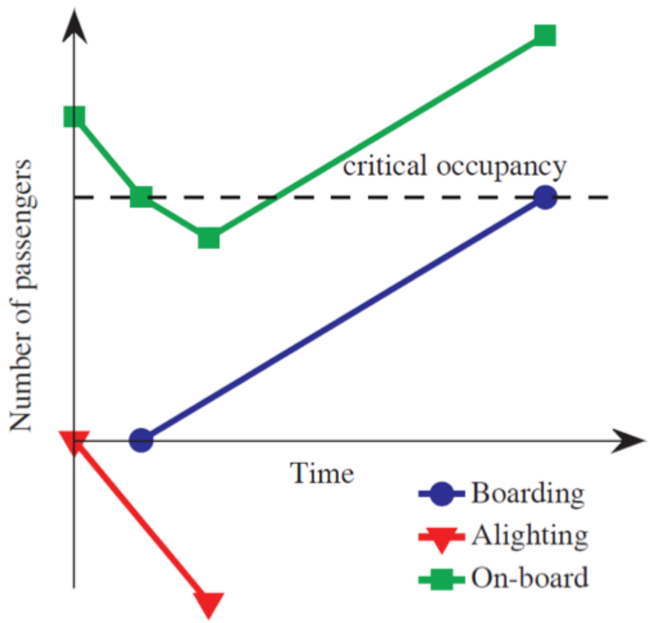
Finding short cuts

Turning Big Data into Smart Data



Dwell time model

Boarding and alighting process



Results of statistical model

Critical occupancy at 63% of total capacity.

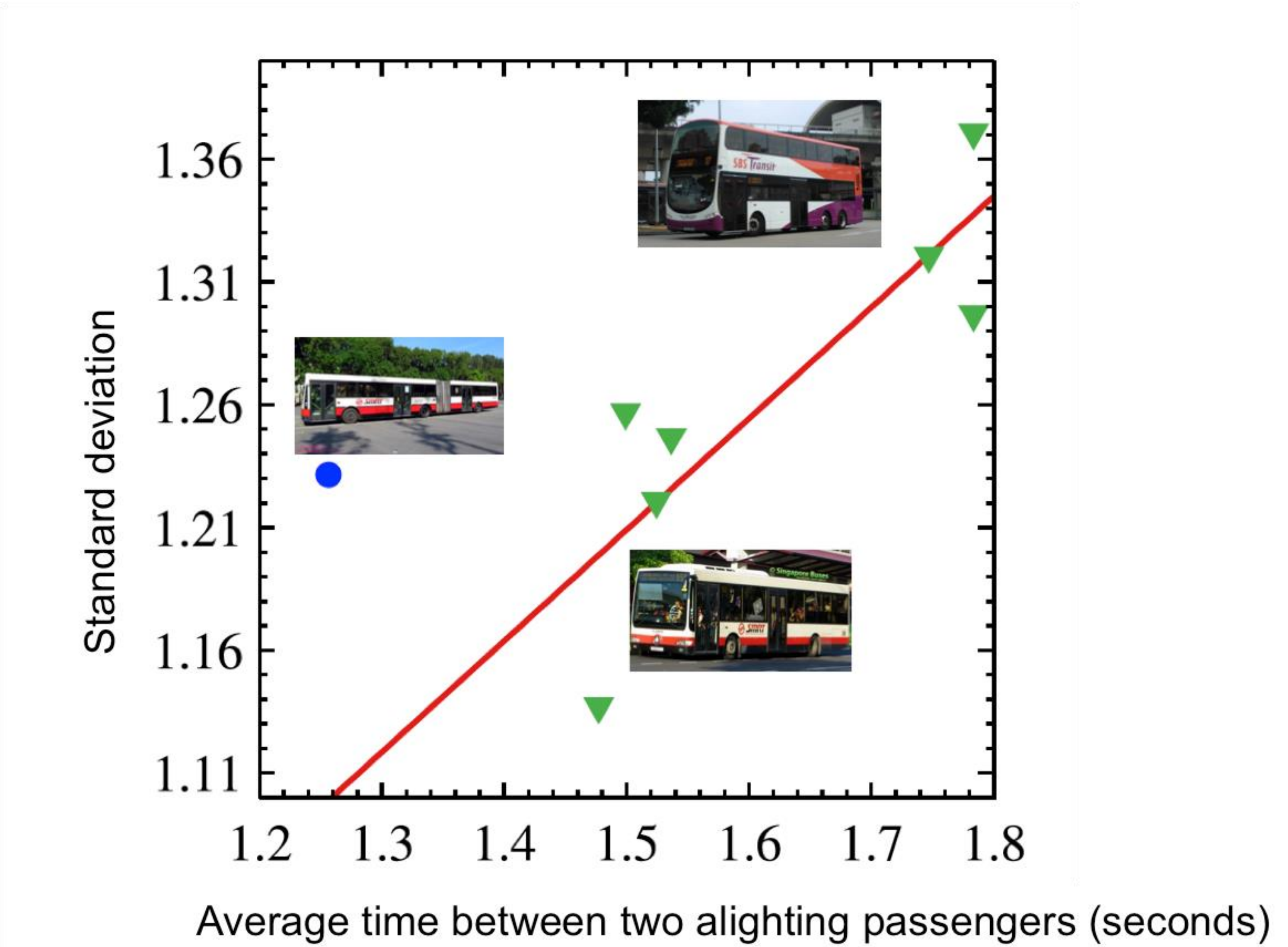
Low floor allows short dwell processes.

Double decker alighting time per pax 0.285 seconds longer.

With higher occupancy and number of boarding and alighting passenger -> shorter activity time

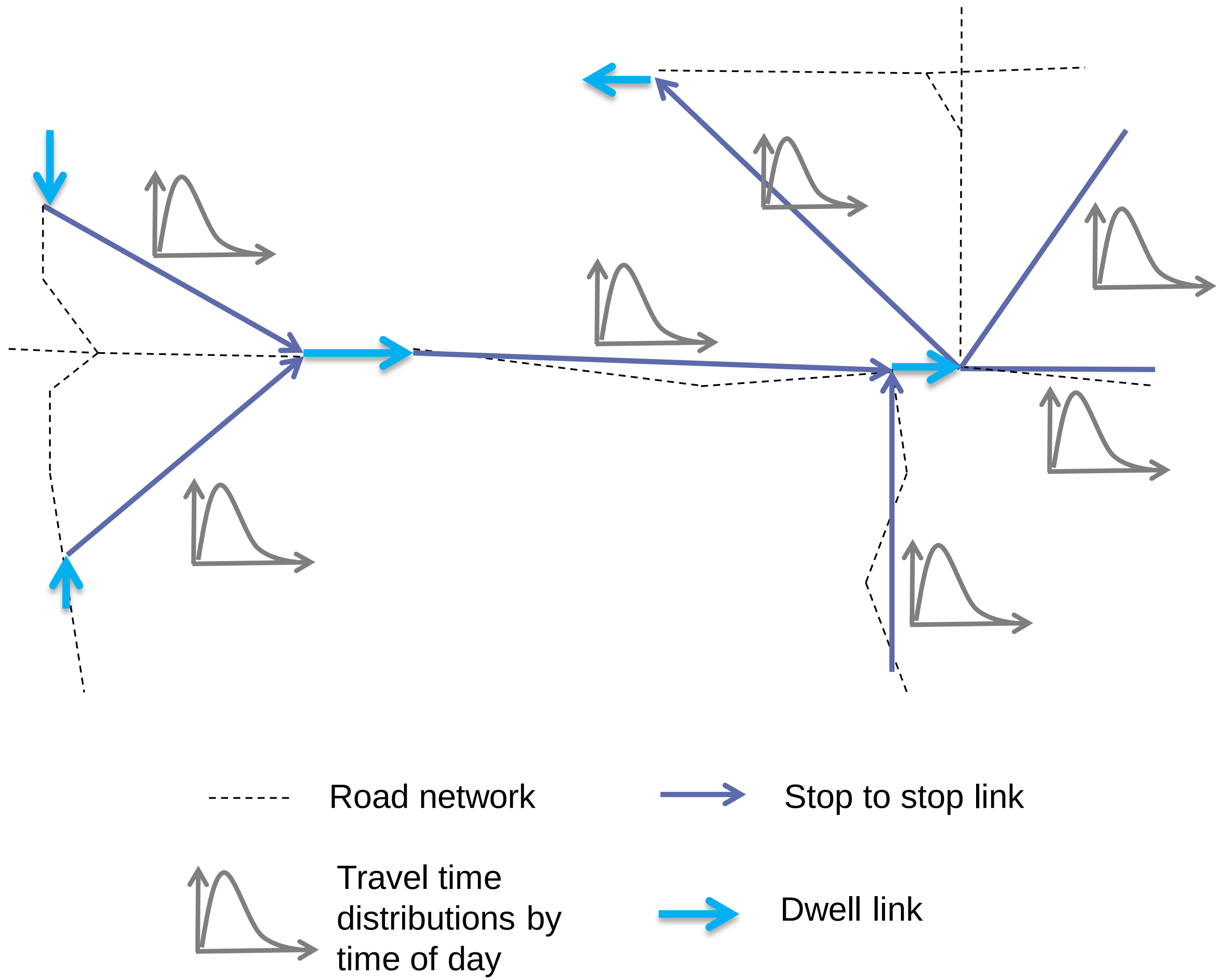
Sun, Lijun, Alejandro Tirachini, Kay W. Axhausen, Alexander Erath and Der-Horng Lee (2014). ‘Models of Bus Boarding and Alighting Dynamics’, *Transportation Research Part A: Policy and Practice* 69: 447–460.

Heteroscedasticity of dwell times



Sun, Lijun, Alejandro Tirachini, Kay W. Axhausen, Alexander Erath and Der-Horng Lee (2014). ‘Models of Bus Boarding and Alighting Dynamics’, *Transportation Research Part A: Policy and Practice* 69: 447–460.

Accounting for travel time variability



Modelling stop to stop travel times

Derive from Smart Card Data records travel times between stops

Each observed travel time between two subsequent stops contitutes one observation

Independent variables to be either derived from smart card data or GIS data, but do not require any other data source (e.g. traffic flow)

Static variables

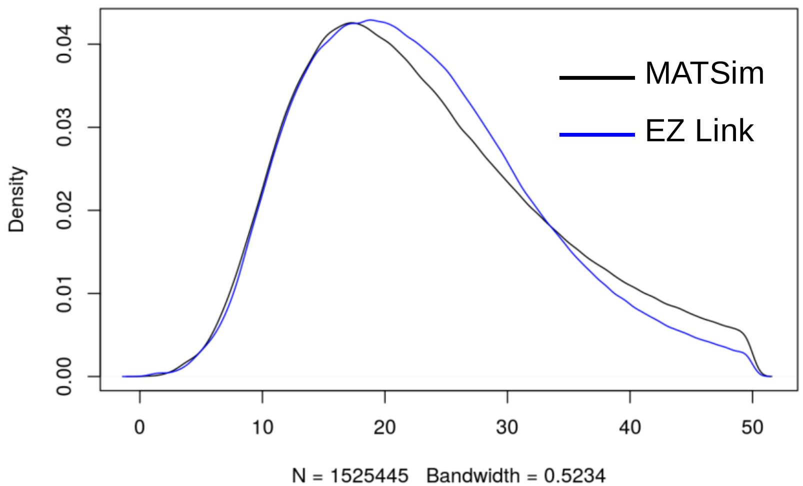
- Availability of bus lane
- Number of intersections
- Number of left/right turns
- Curviness
- Deviation from crowfly distance
- Number of traffic lights
- Intersection density

Time-dependent variables

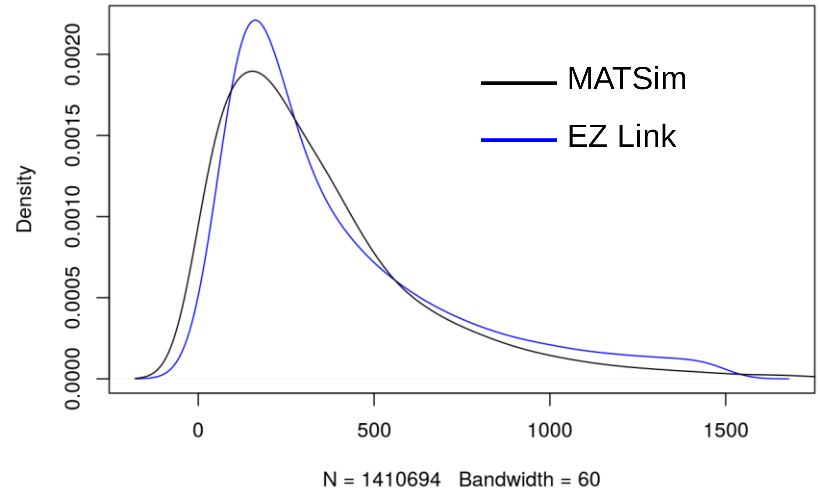
- Boarding/alighting activites in 500m radius

Validation

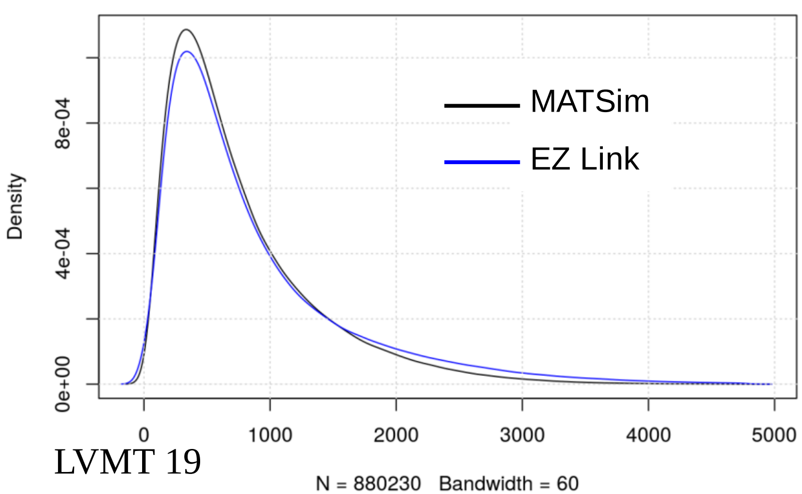
Bus speed



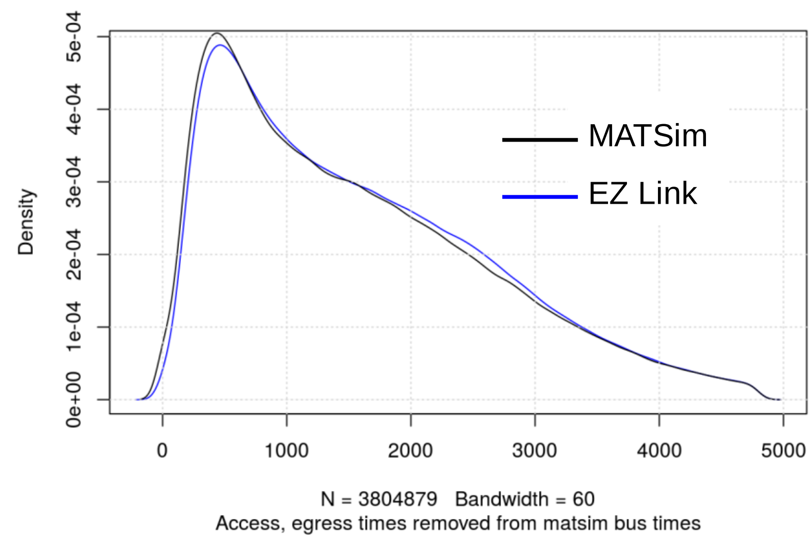
Transfer times



Trip duration (Bus)



Journey duration all modes



Case study: network reconfiguration

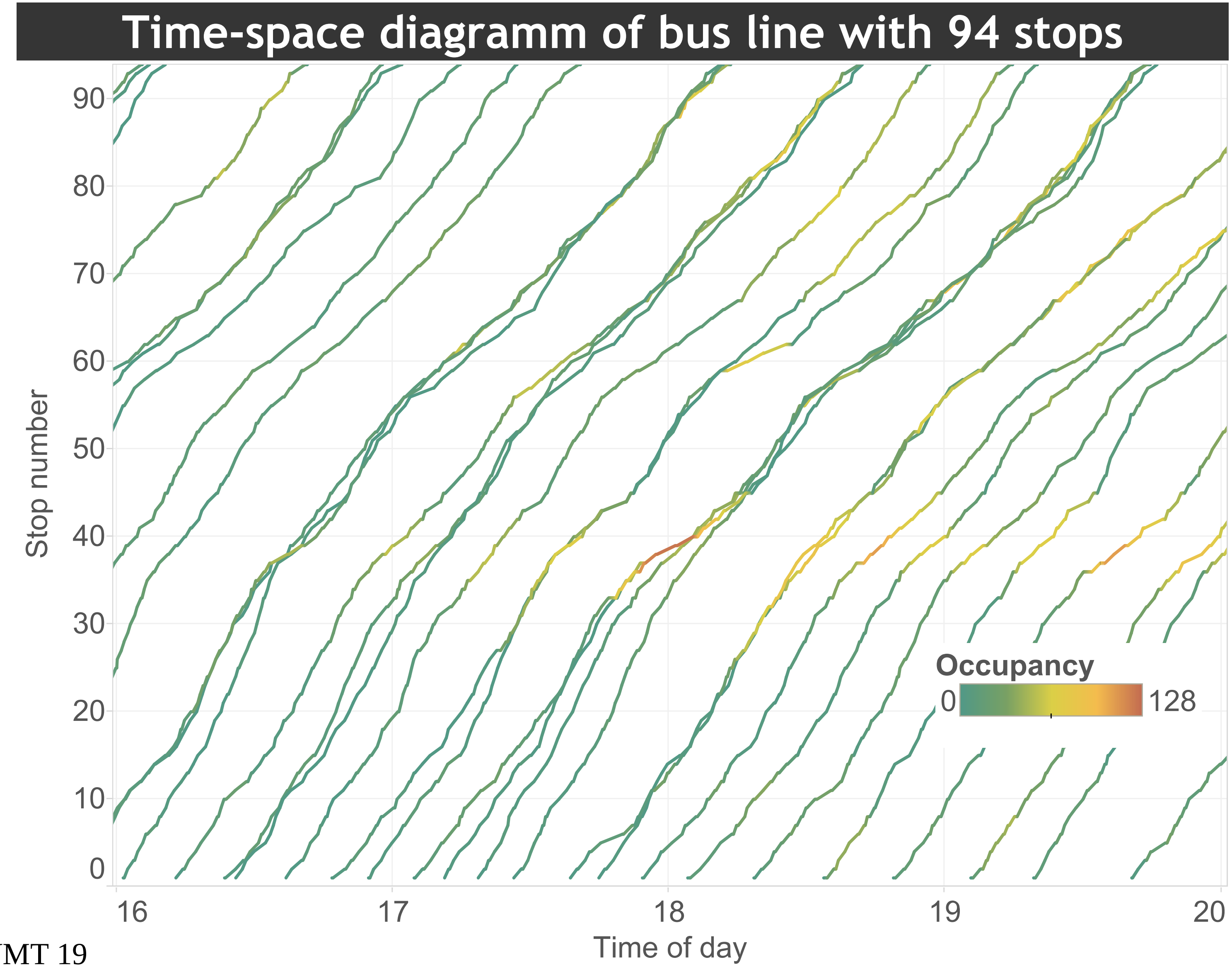
Evaluation of new services and routes:

- How can new network designs improve reliability and tackle overcrowding?
- How many passengers will be attracted by a new service?

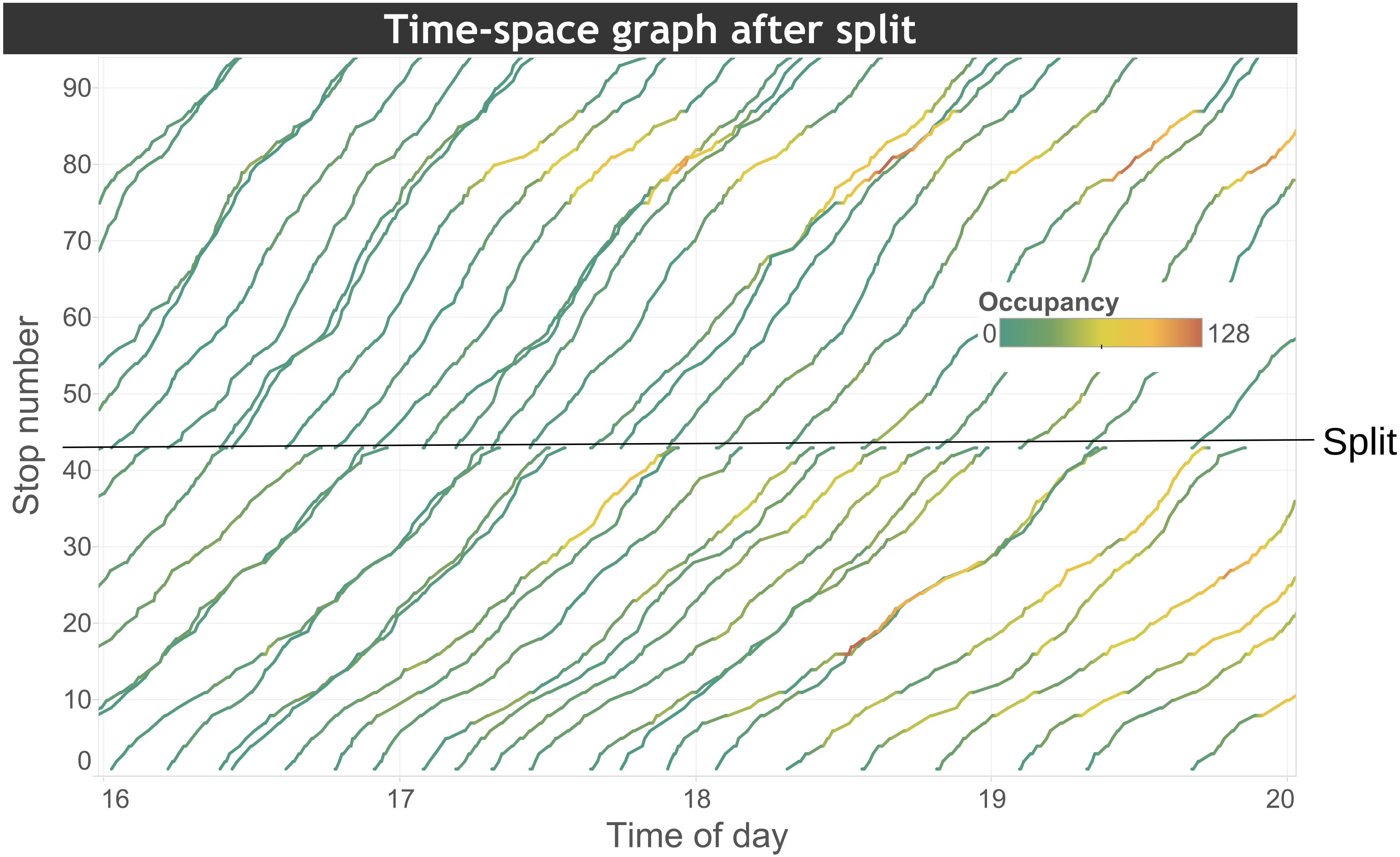
Simulation and analysis:

- A full day simulated in just about 40 minutes.
- Leverage on off-the-shelf business analytic software for interactive analysis.

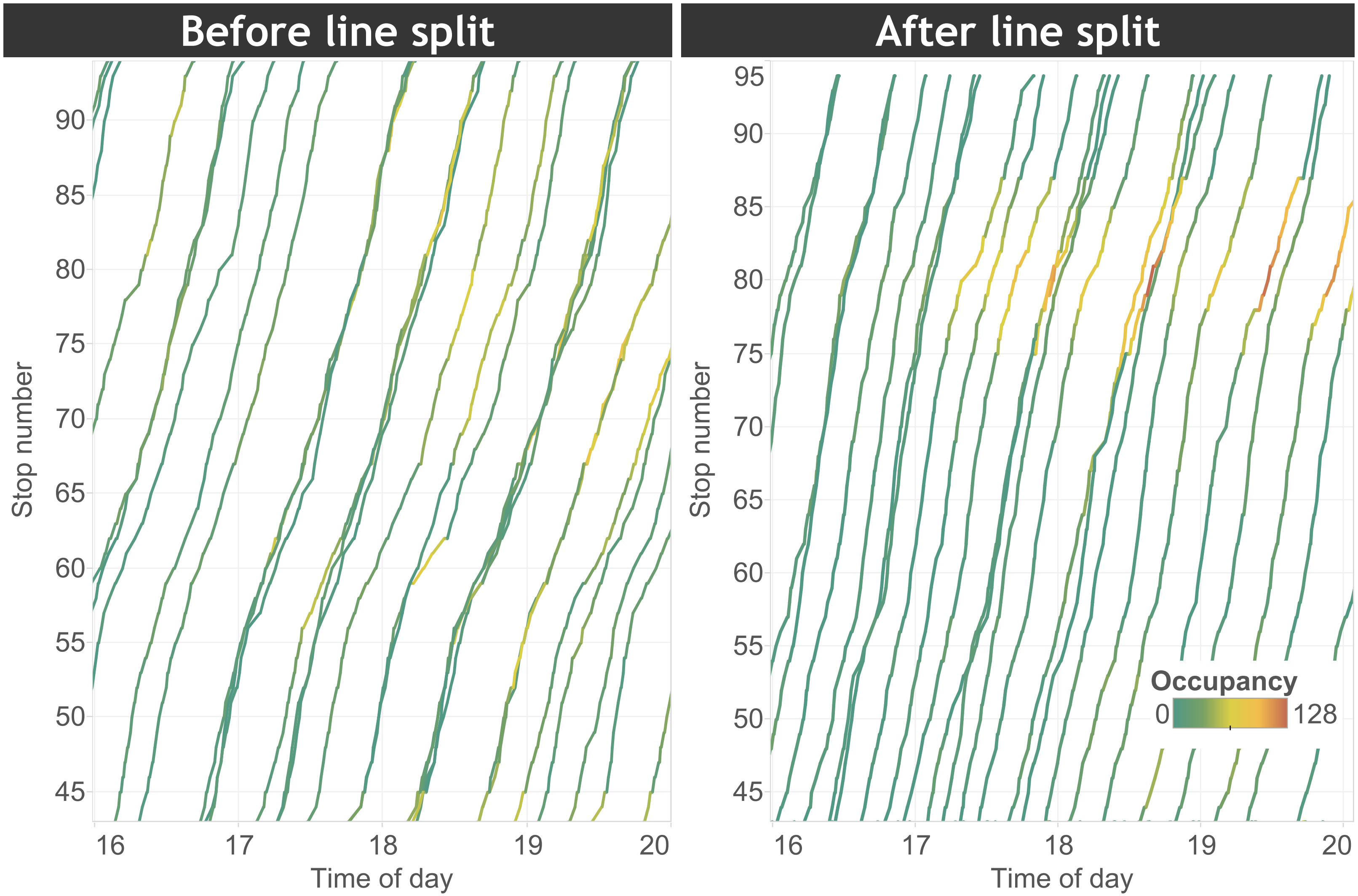
The reliability of a long bus line



The effect of splitting the line



Reliability before and after line split



Challenges

Challenges for MATSim

- Econometric estimation of the whole day scoring function

- Increase the size and variance of the implicit choice set
- Link to a log-sum formulation (Chakirov)

- Accelerating the iterative equilibrium search

- Gridlock modeling (& stability of equilibrium)
- Modelling “irrational/uninformed” behaviours

- Generation of artificial social networks in the agent-population
- Co-generation of joint activities

- Multiple agent-type equilibria, e.g. stores, PUDOs, agents

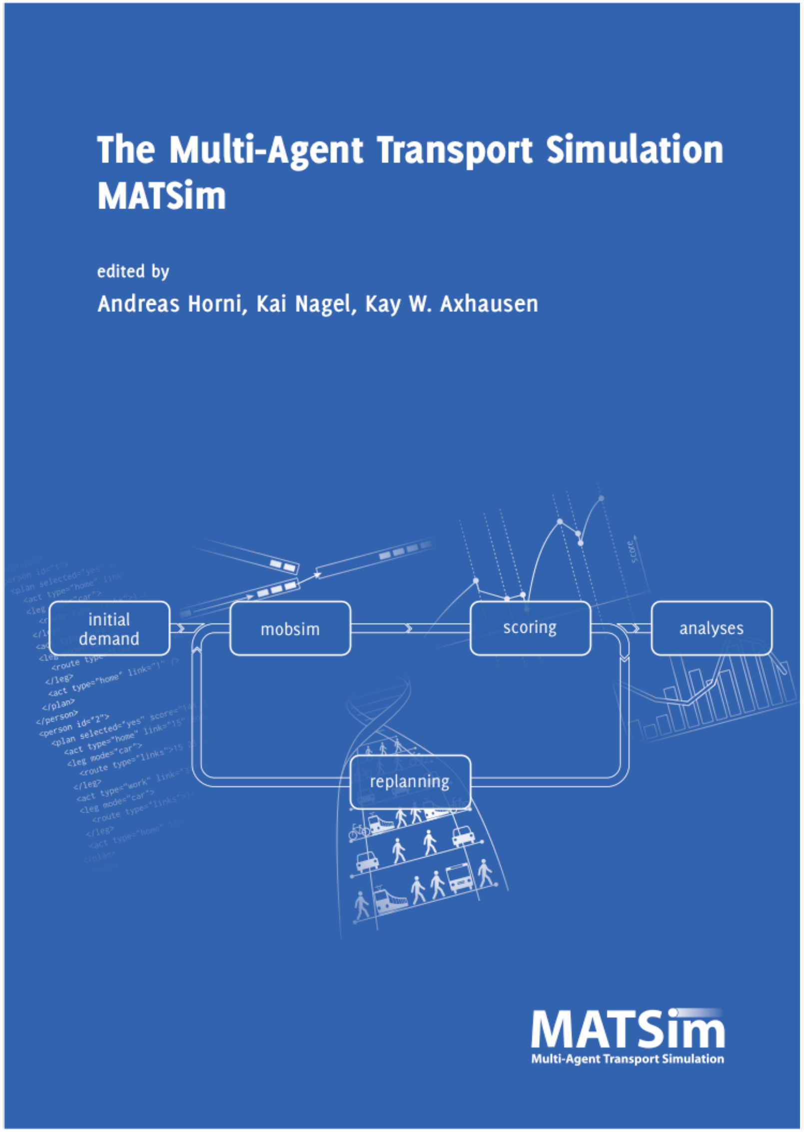
Questions ?

www.matsim.org

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

www.senozon.com
www.simunto.com

Questions ?


The Multi-Agent Transport Simulation
MATSim
edited by
Andreas Horni, Kai Nagel, Kay W. Axhausen
initial demand
mobsim
scoring
analyses
replanning
MATSim
Multi-Agent Transport Simulation

Appendix

Conclusions for modelling

Conclusions for modelling

We have to account for

self-selection everywhere

And we have to account for

spatial-temporal correlations and
joint choices producing the queues

Conclusions for modelling

We have to better understand the

system capacities (e.g. mMFD)

And the willingness to

costly change (individual/joint) behaviour

and

joint decision-making (group; collectives)