Behavioral calibration of a large-scale travel behavior microsimulation

Gunnar Flötteröd[1], Yu Chen, Marcel Rieser, Kai Nagel[2]

December 17, 2009

[1] Ecole Polytechnique Fédérale de Lausanne
[2] Technical University of Berlin

TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

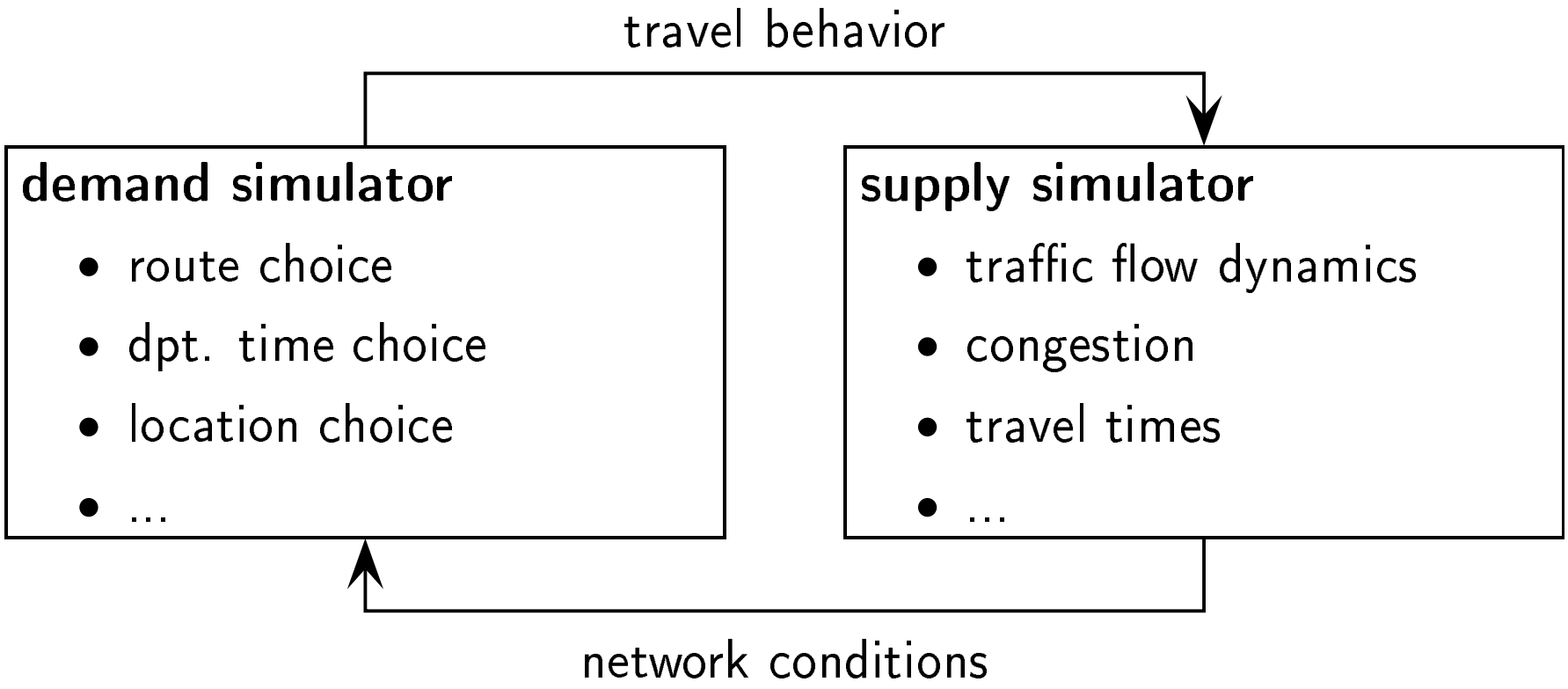
Introduction and motivation

- Dynamic traffic assignment (DTA) captures interactions of
  - a travel demand model (typically route choice)
  - a supply model (mobility simulation)
- DTA *microsimulations* have the potential to
  - equilibrate more than route choice (e.g., dpt. time, mode)
  - capture arbitrary demand heterogeneity
  - handle complex and very large systems
- however
  - little mathematical framework available
  - calibration has been fairly ad hoc

This article presents real-world results using a mathematically consistent calibration methodology.

Outline

General DTA microsimulation structure



The MATSim DTA microsimulation

- all-day travel behavior of an **agent** is captured in its **plan**
- equilibrates route + departure time + mode choice
- runs in two stages
  1. choice set generation: update choice set during iterations
  2. choice: run demand simulator based on stable choice set
- choice stage deploys multinomial logit model where

$$P_n(i) \sim \exp(V_n(i))$$

is probability that agent n chooses plan i with utility $V_n(i)$

Outline

Cadyts – Calibration of dynamic traffic simulations

- calibration framework for iterated DTA microsimulations
- calibrates arbitrary choice dimensions from traffic counts
- compatible with many demand and supply simulators
- freely available under GPL:[3] `transp-or2.epfl.ch/cadyts`

[3] GNU General Public License

Basic functioning

- simulator implements plan choice distribution $P_n(i)$
- account for measurements observed in the network
  - $y_a(k)$ is traffic count on link a in time step k
  - $\sigma_a^2(k)$ is the variance of the according error
- plan choice distribution given the measurements is

$$P_n(i|\{y_a(k)\}_{ak}) \sim P_n(i) \prod_{ak \in i} \exp\left(\frac{y_a(k) - q_a(k)}{\sigma_a^2(k)}\right)$$

  where $q_a(k)$ is the simulated flow on link a in time step k
  - assumes normal error and low congestion
  - more general solution exists but is less intuitive
  - the above works intuitively like a controller

Application to MATSim (1/2)

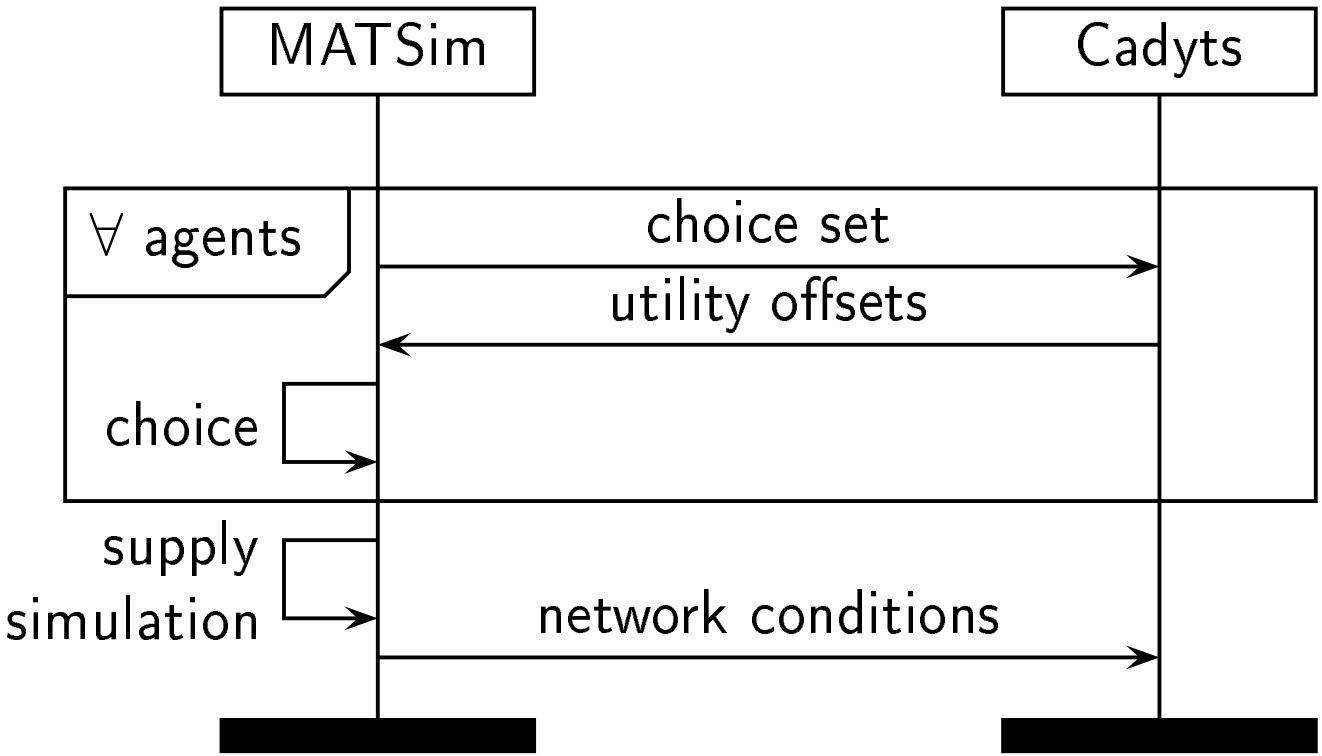
- insert MATSim choice model $P_n(i) \sim \exp(V_n(i))$ into the calibrated choice distribution:

$$P_n(i|\{y_a(k)\}_{ak}) \sim \exp\left(V_n(i) + \sum_{ak \in i} \frac{y_a(k) - q_a(k)}{\sigma_a^2(k)}\right)$$

- increases the utility of plans that improve the measurement reproduction (and vice versa)

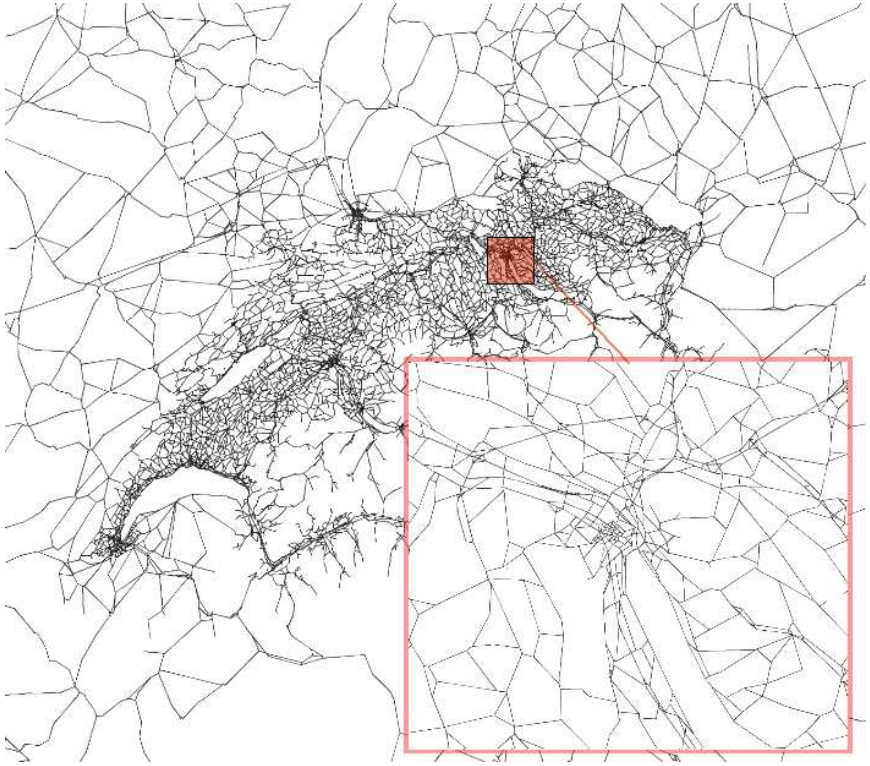
Application to MATSim (2/2)

msc one iteration of calibrated simulation



Outline

Zurich case study



- network with 60 492 links and 24 180 nodes
- 187 484 agents
- hourly counts from 161 counting stations
- jointly estimate route + dpt. time + mode choice

TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

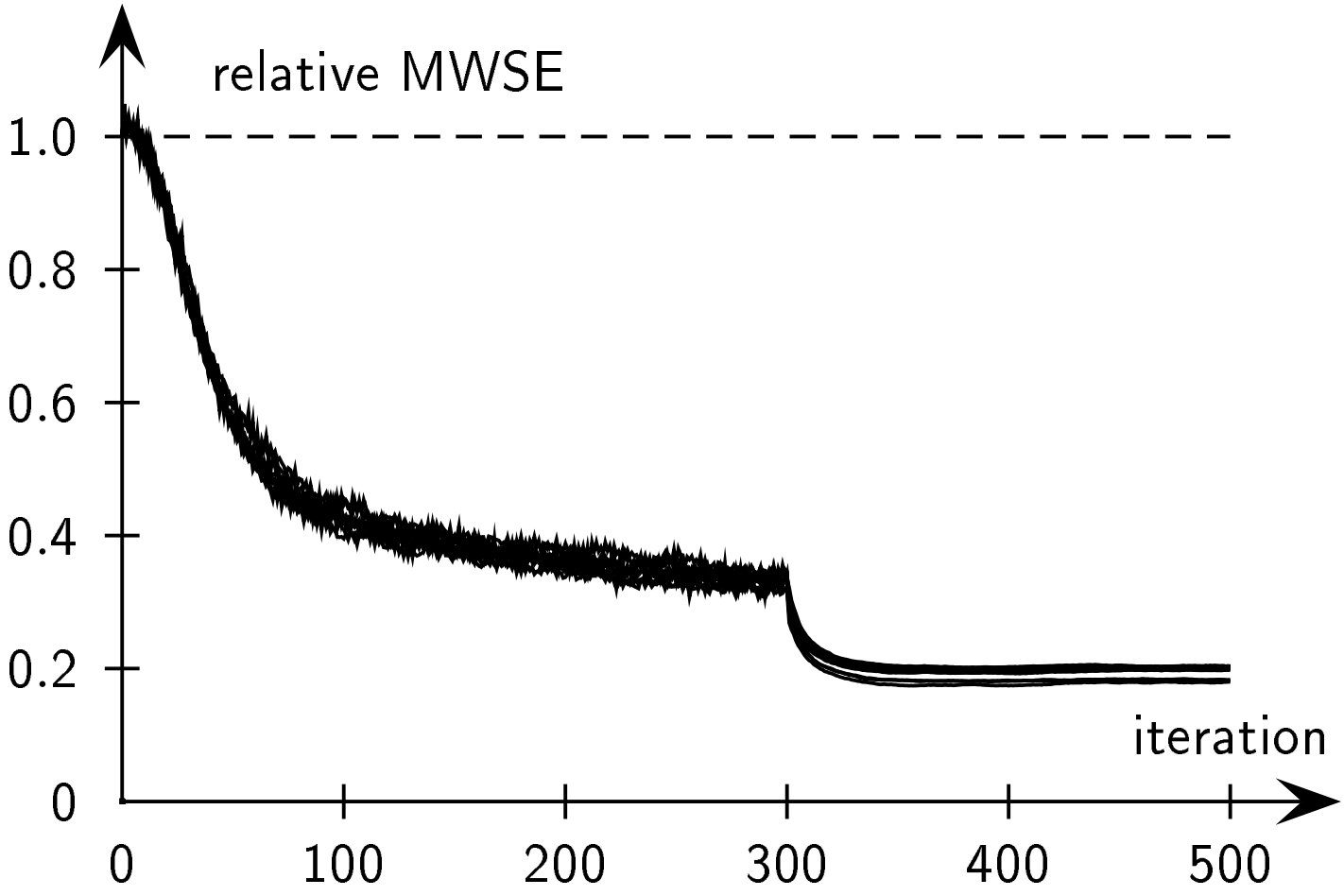
Cross-validation

- mean weighted square error MWSE

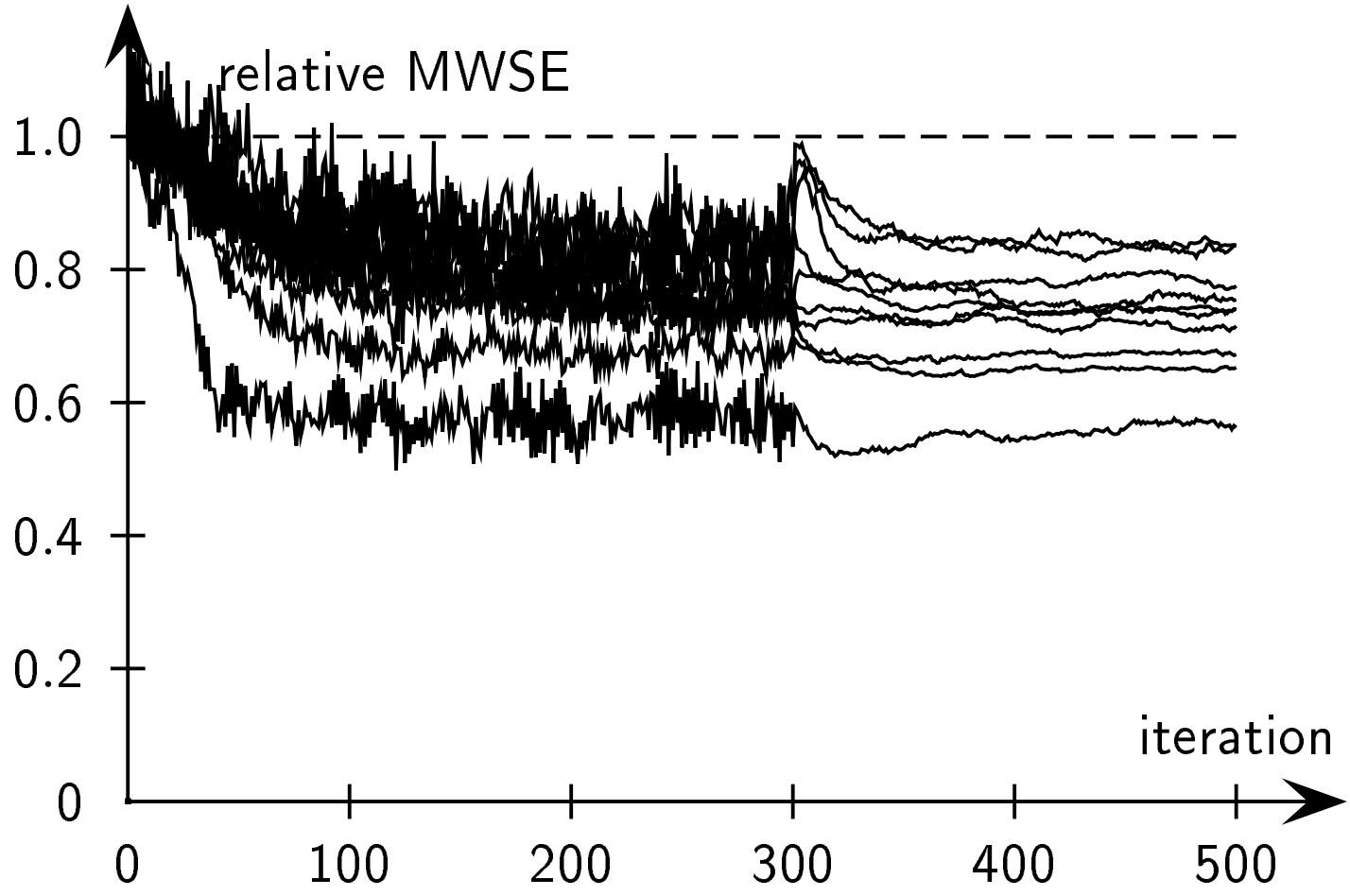
$$\text{MWSE} = \left\langle \frac{(y_a(k) - q_a(k))^2}{2\sigma_a^2(k)} \right\rangle_{ak}$$

- split counting stations into 10 disjoint sets
- run 10 experiments, in each experiment
  - use 9 out of 10 sensor sets for estimation
  - use remaining sensors for validation

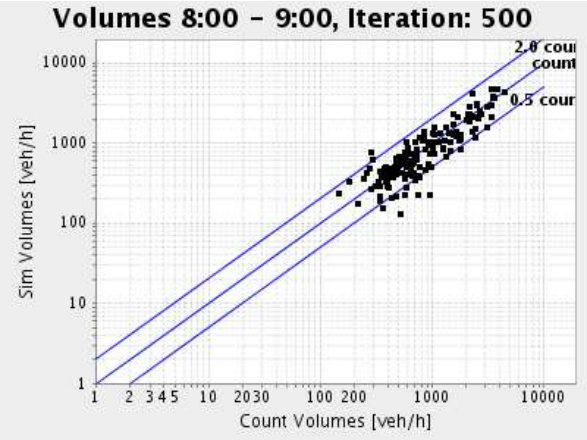
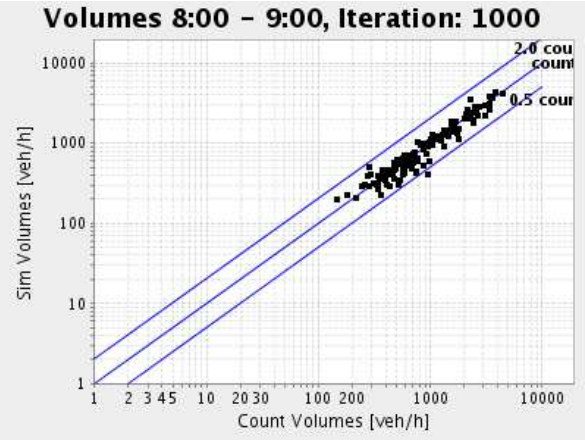
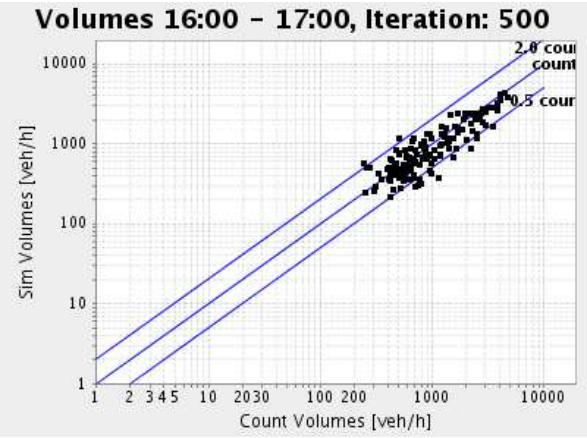
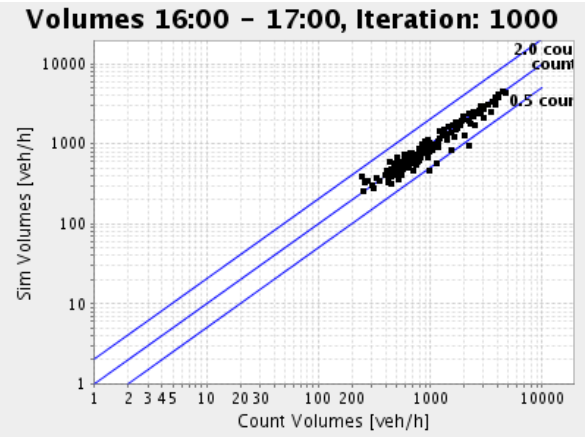
Measurement reproduction results



Cross-validation results



Scatterplots

	plain simulation	calibrated simulation
morning		
afternoon		

TRANSP-OR

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Computational performance

- experiments were run on a heterogeneous cluster
- raw running times are *not comparable*
  - 500 iterations of **plain simulation** took 72 h on a Dual-Core AMD Opteron Processor 2222 machine with 32 GB RAM
  - 500 iterations of **calibrated simulation** took 36 h on a Intel Xeon CPU X5550 with 48 GB RAM
- calibration takes place *within* the iterations of the simulation
- speculation: calibration *may even accelerate* simulation in that it induces drift to plausible system state

Outline

Summary, conclusion, outlook

- joint calibration of route + dpt. time + mode choice for 190k agents on 60k link network with low computational overhead
- analytical DTA models do not have an edge over simulation-based ones in terms of calibration any more
- also adjust the parameters of the choice model – likely to require additional data sources