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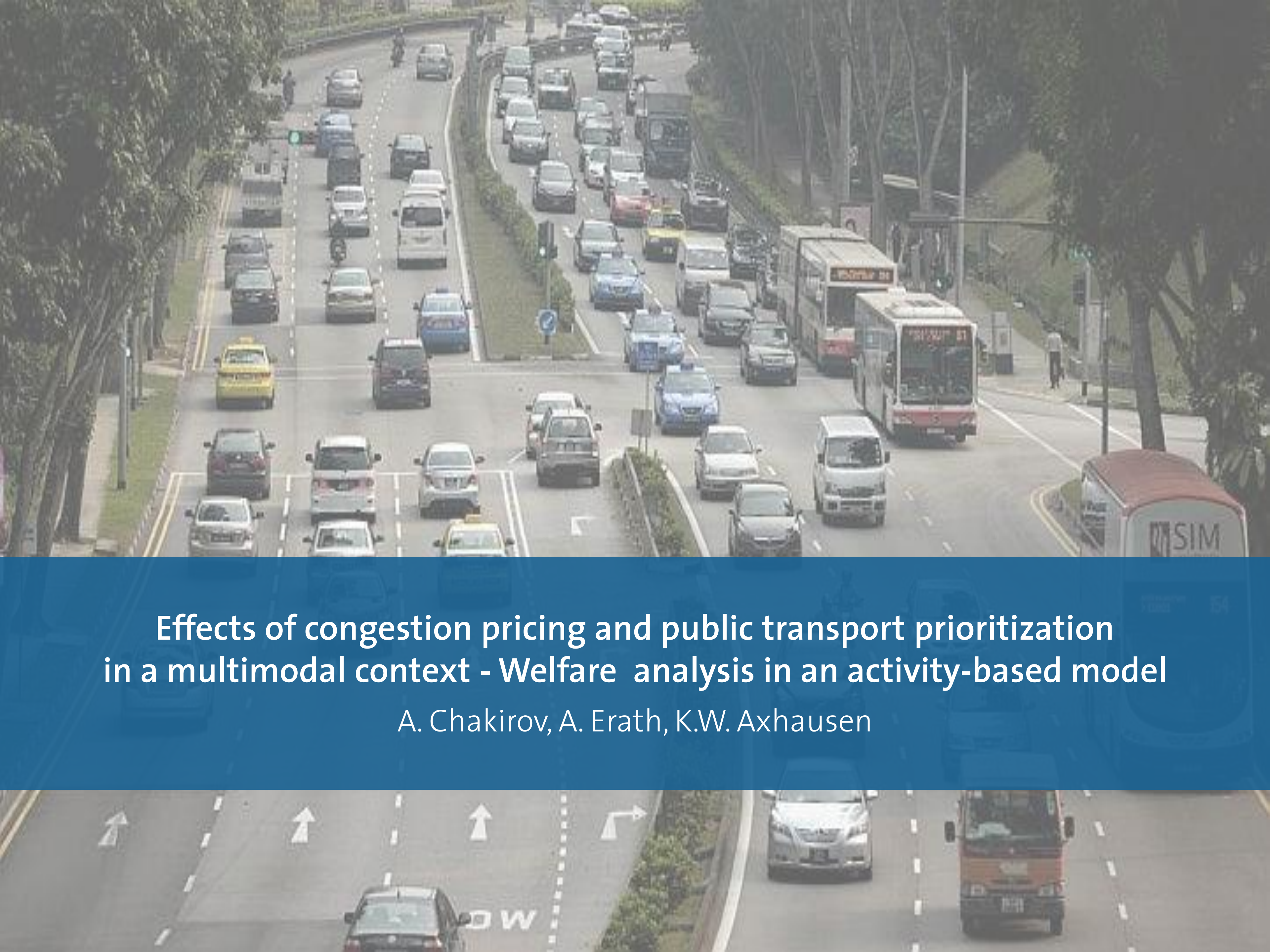


Effects of congestion pricing and public transport prioritization in a multimodal context - Welfare analysis in an activity-based model

A. Chakirov, A. Erath, K.W. Axhausen

Motivation: Bus lanes vs. Road pricing?

“[...] *reserved bus lanes and, inferentially, separate expressway ramps and other forms of preferential access by buses to road capacity are capable of substantially ameliorating our apparent political inability to price peak-period road services efficiently.* “

(Mohring, 1983)

Berglas et al. (1984) showed that under certain assumptions the mixed-traffic operation is never superior and is more likely to be inferior than providing separate lanes for buses and cars.

“ [...] car congestion pricing, optimal transit subsidization and dedicated bus lanes produce an important and relatively similar social benefit”

(Basso and Silva, 2010)

How can agent-based simulation tools can be used to evaluate policy gains from dedicated bus lanes vs. first-best road pricing?

MATSim: Multi-Agent Transport Simulation

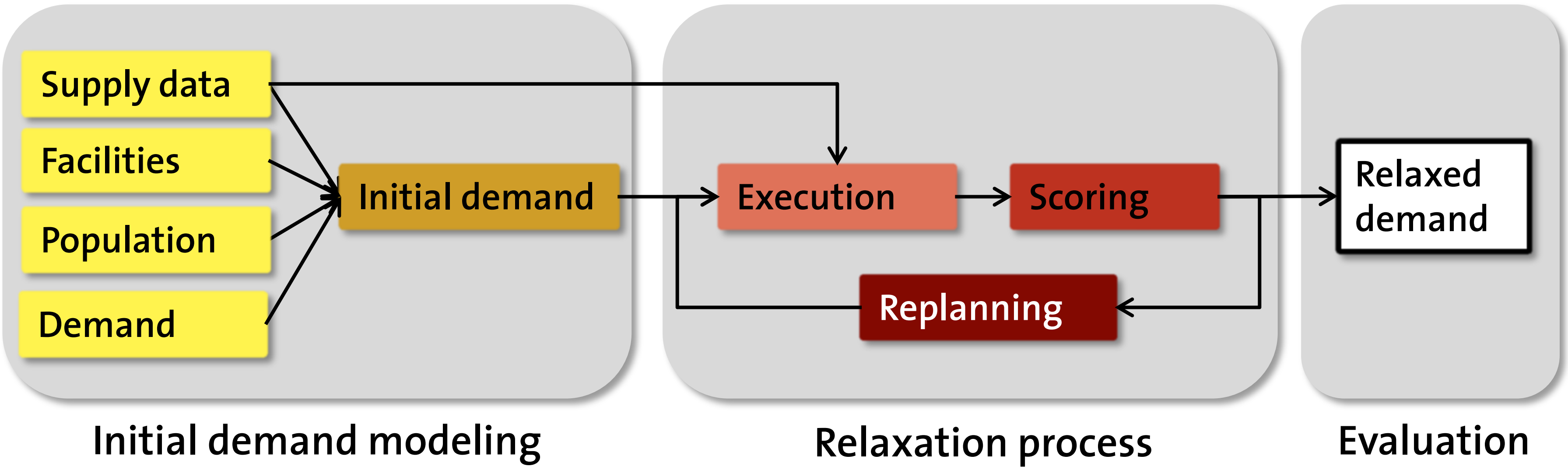
- Stochastic User Equilibrium
- Boundary/initial conditions (land use, transport network, demographics, etc.)
- List of choice dimensions that are adapted
- Parallel Queue Model Approach
- Time step: 1sec over 24h period

Choice dimensions

- Route choice
- Mode Choice
- Departure time choice
- (Secondary activity-location choice)

Constraints

- Flow and storage capacity of the network
- Bus vehicle capacity
- Dwell times



MATSim: Details of Public Transport and Road Pricing

Public Transport

- Interaction of bus and cars (incl. bus bays)
- Frequency and Fare
- Vehicle capacity
- Dwell times
- No overtaking
- No comfort variability (e.g. crowding, seat availability)

Road Pricing

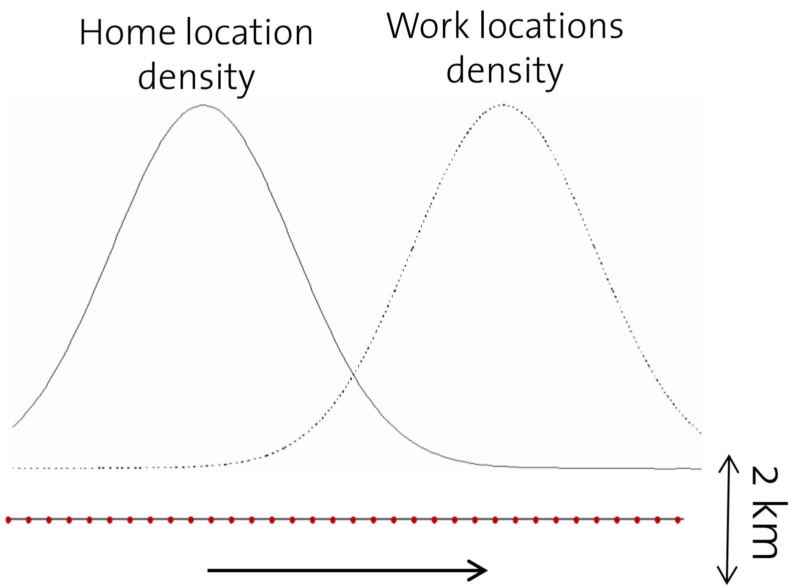
- Additional cost of every or selected links

First – best pricing implemented according to *Lämmel and Flötteröd (2009) Towards System Optimum: Finding Optimal Routing Strategies in Time-Dependent Networks for Large-Scale Evacuation Problems , KI 2009: Advances in Artificial Intelligence, 5803, pp. 532-539.*

External cost: $$C(t_0) \approx t^e(t_0) - \tau^{free} - t_0.$$

Queue encountered when entering the link at $t_0$to dissolves at $t_e(t_0)$

Corridor scenario - Supply



20km corridor with bus network
(Bus stop every 600m)

- 20000 agents (10% captive pt riders)
- Distance between bus stops: 600m
- Bus frequency: 2 min
- Bus capacity: 139
- Bus length: 12m
- Dwell time per passenger: 1 sec

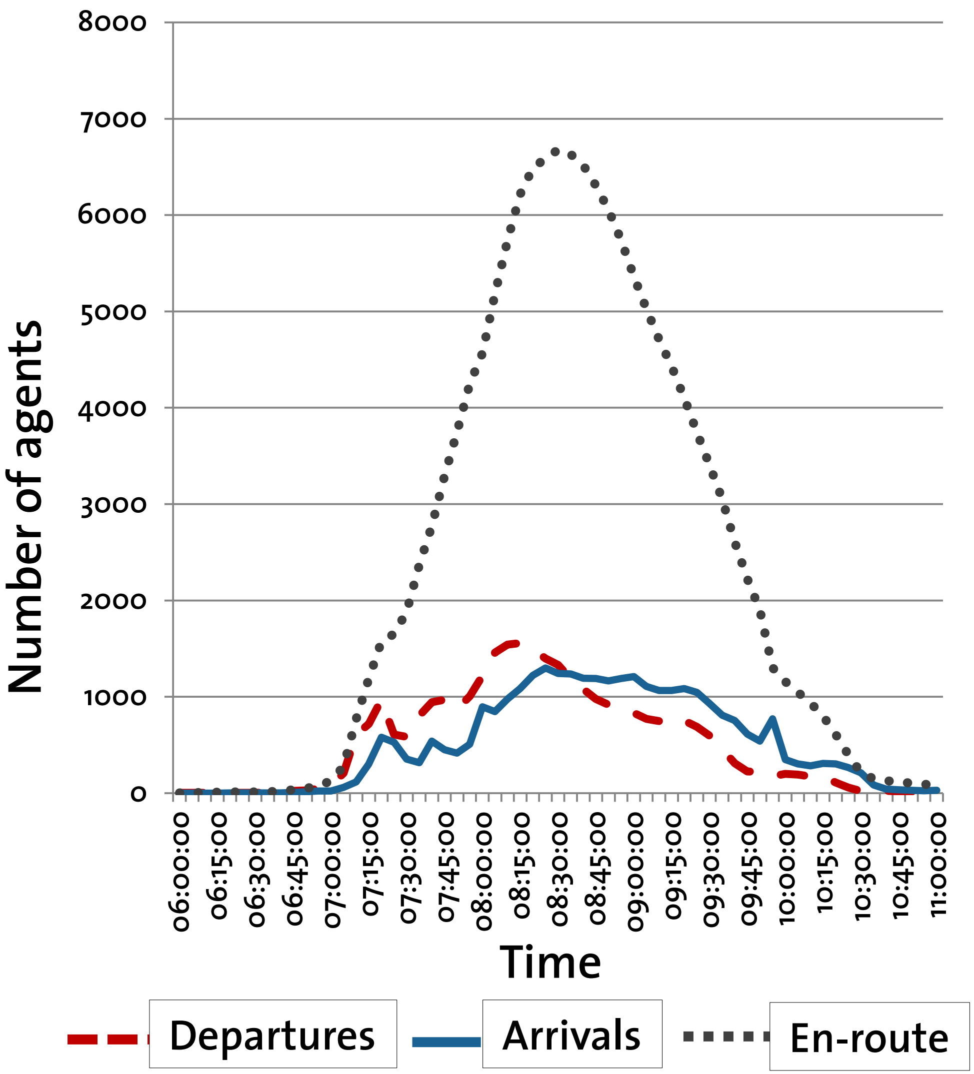
3 Scenarios:

Base scenario	3 mixed lanes
Bus lane scenario	2 car lanes 1 bus lanes
First-best road pricing	3 mixed lanes

Lane capacity: 1000 veh/h

Bus lane capacity: $143 * \frac{60\ min}{2\ min} = 4290$ pax/h

Initial Demand and Behavioral parameters



*)

$\beta_{tr,car}$	0	[utils/h]
$\beta_{v,pt}$	−0.18	[utils/h]
$\beta_{w,pt}$	−0.096	[utils/h]
$\beta_{a,pt}$	0	[utils/h]
$\beta_{e,pt}$	0	[utils/h]
β_{c}	−0.062	[utils/AUD]
β_{perf}	+0.96	[utils/h]
$VTTS_{tr,car}$	15.48	[AUD/h]
$VTTS_{v,pt}$	18.39	[AUD/h]
$VTTS_{w,pt}$	17.03	[AUD/h]
$VTTS_{a,pt}$	15.48	[AUD/h]
$VTTS_{e,pt}$	15.48	[AUD/h]

$$\beta_{0,car} = -0.3 \text{ [utils]}$$
$$\beta_{tr,walk} = -0.27 \text{ [utils/h]}$$
$$\beta_{earlyDeparture} = -2.88 \text{ [utils/h]}$$
$$\beta_{lateArrival} = -2.88 \text{ [utils/h]}$$
$$\beta_{lineSwitch} = -0.016 \text{ [utils]}$$

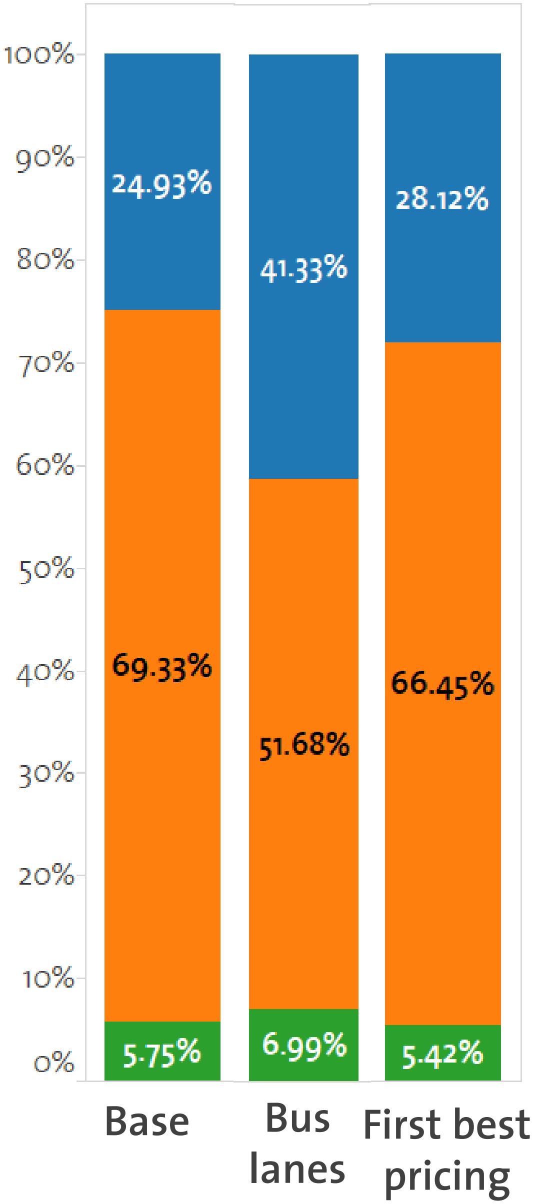
Car: 0.40 cent / km
PT: 3.50 AUD per ride

* Parameters used by Kaddoura,I., Kickhöfer, B., Neumann, A. and Tirachini, A. (2012) Public transport supply optimization in an activity-based model: Impacts of activity scheduling decisions and dynamic congestion, presented at LATSIS 2012.

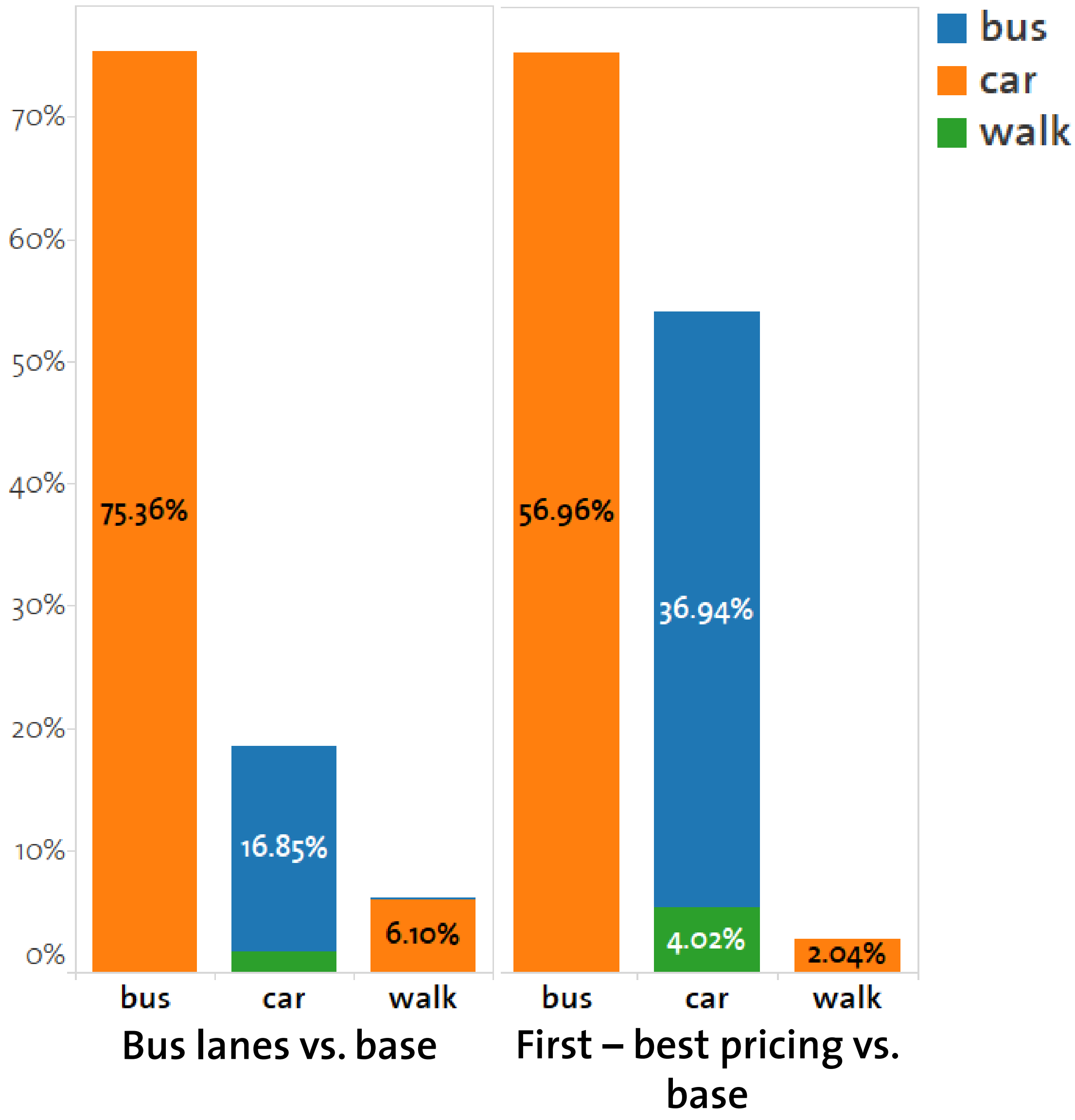
Corridor Scenario – Key Numbers

	Base scenario	Bus lanes scenario	First – best pricing
Avg. Car Speed	22.72 km/h	23.96 km/h	36.92 km/h
Avg. Bus Speed	28.24 km/h	37.24 km/h	36.72 km/h
Avg. Journey Travel Time	36.18 min	39.99 min	24.52 min
Car	27. 97 min	27.34 min	14.00 min
Bus	58.30 min	55.84 min	47.08 min
Walk	39.18 min	39.87 min	36.44 min
Avg. In-vehicle Distance	7076 m	6910 m	7072 m
Car	7894 m	7941 m	7558.11 m
Bus	6432 m +(1559 m)	6789 m + (1693 m)	6433 m + (1559 m)
Walk	1507 m	1533 m	1401 m

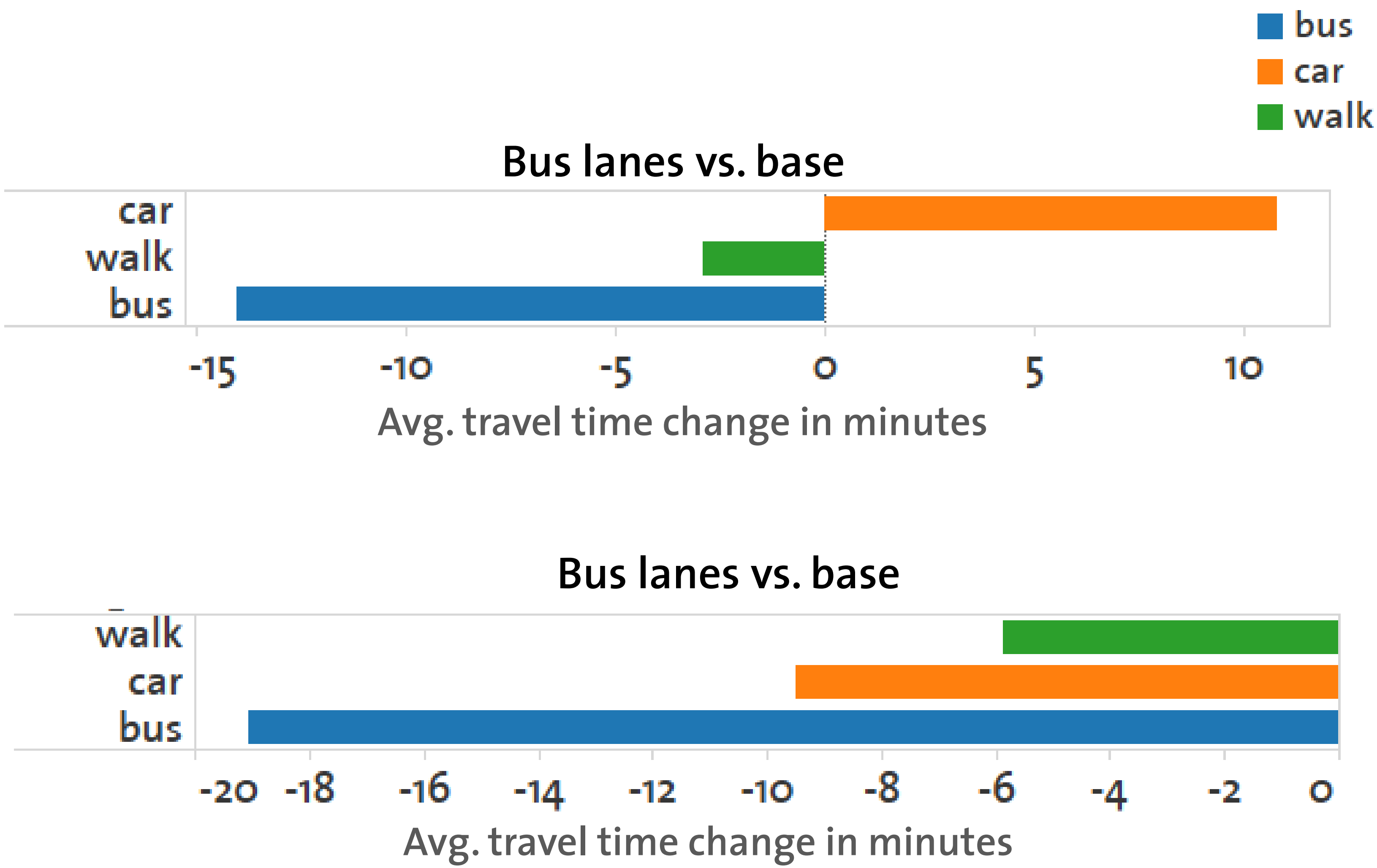
Corridor – Mode share



Where do the "mode switchers" come from?



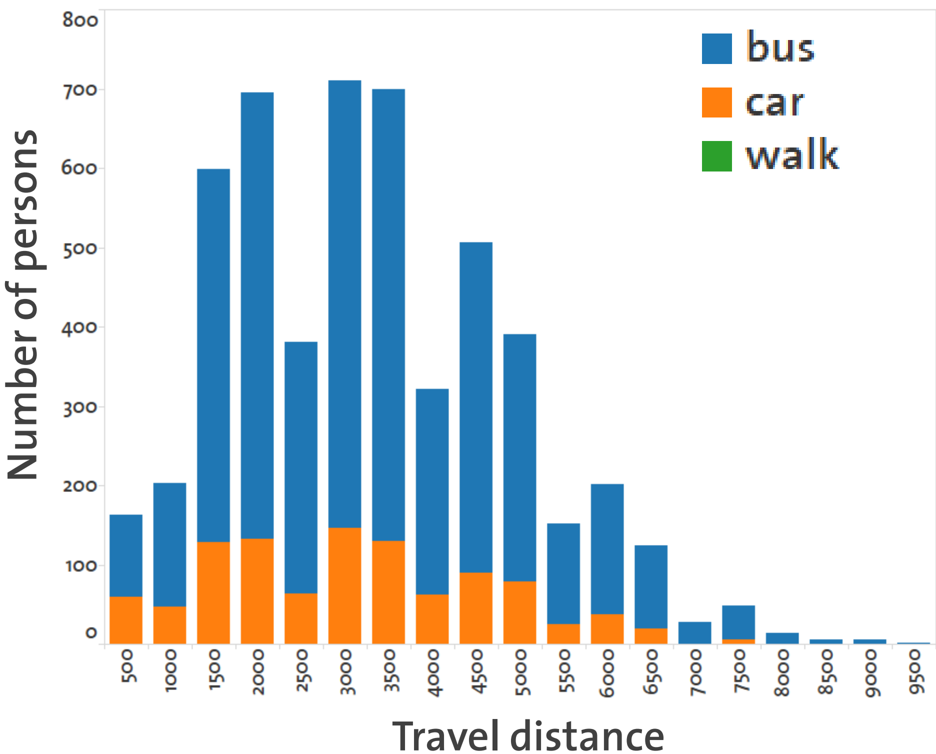
Corridor – Travel time changes compared to base scenario



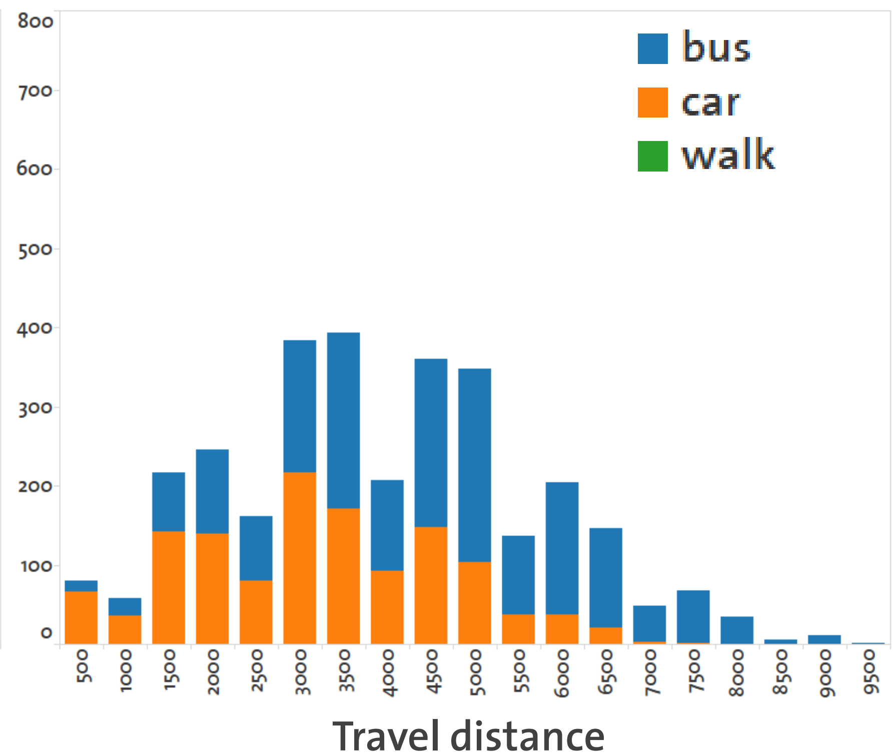
Corridor – In-vehicle distance of mode changers

How far do persons who switch modes go?

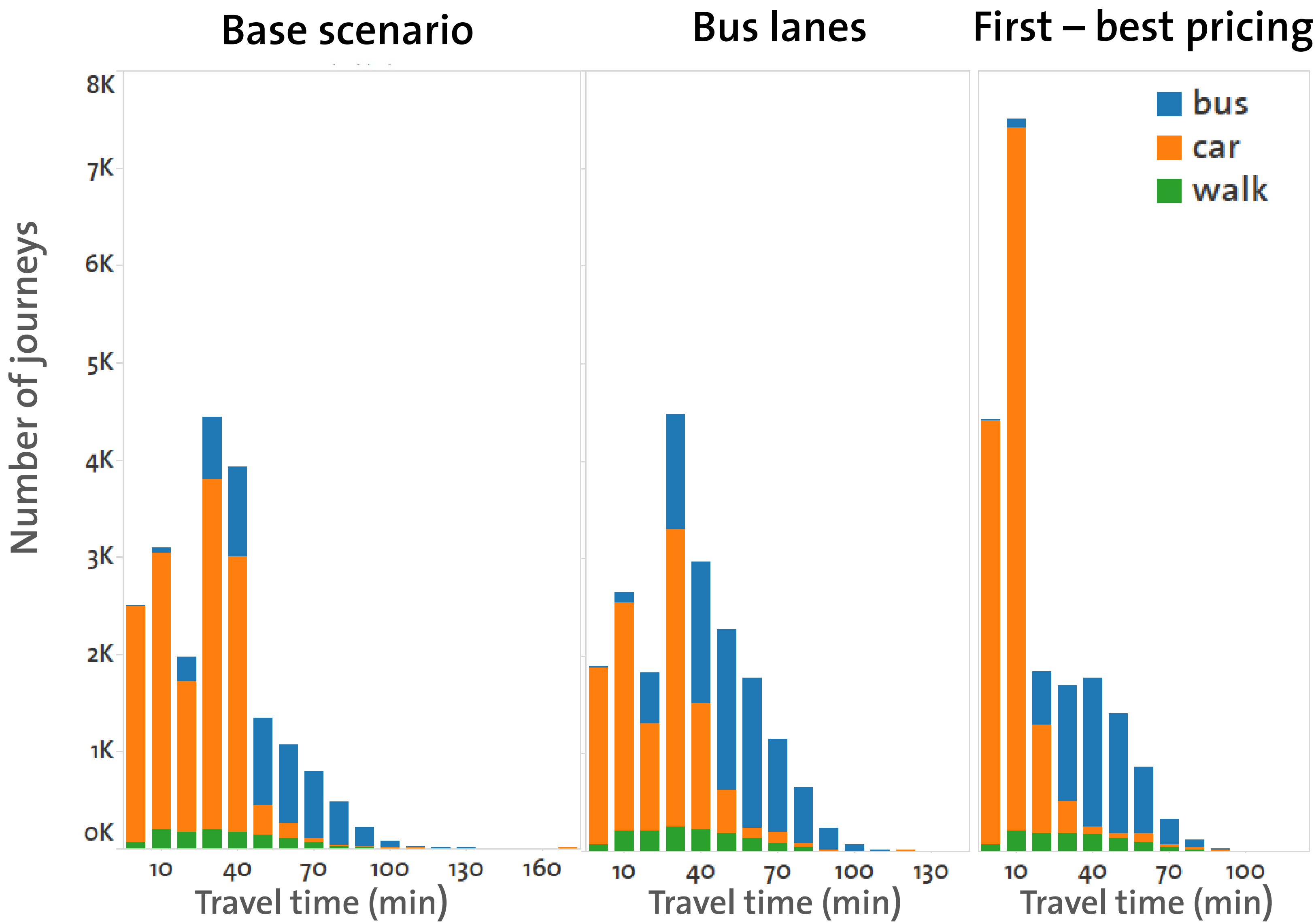
Bus lanes vs. base



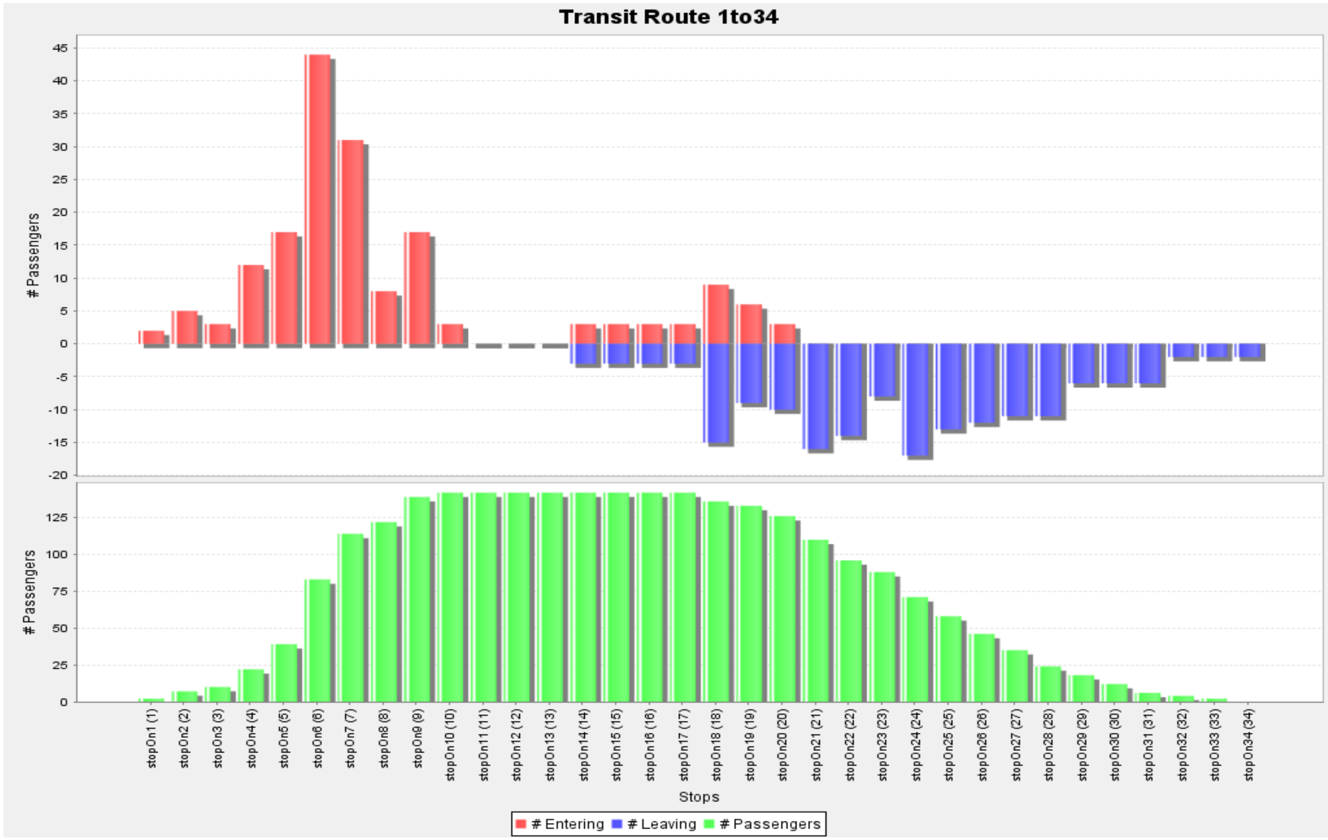
First – best pricing vs. base



Corridor – Travel time distribution



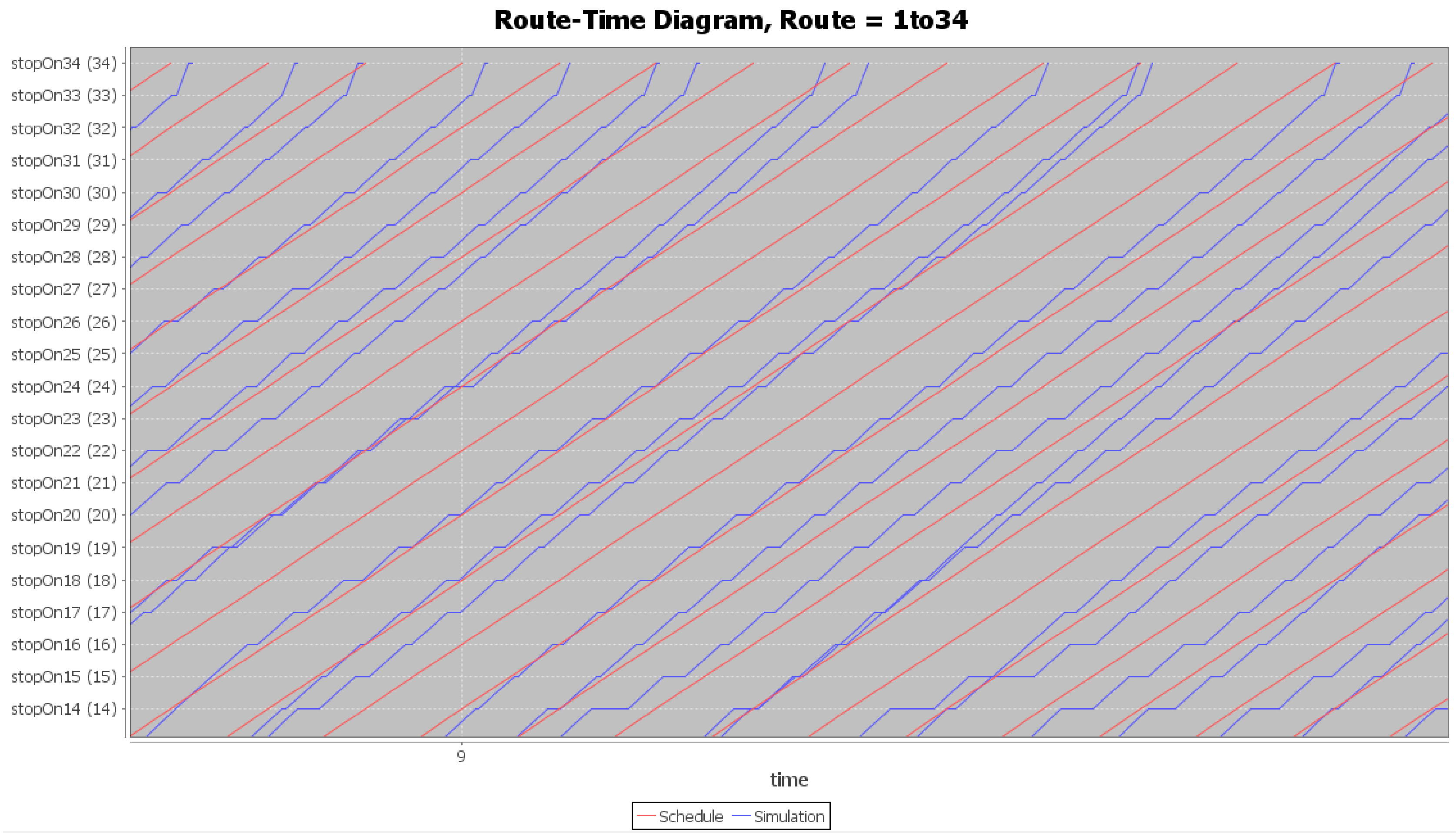
Corridor – Bus Occupancy – Service starting at 08.10 am



Bus capacity constraint

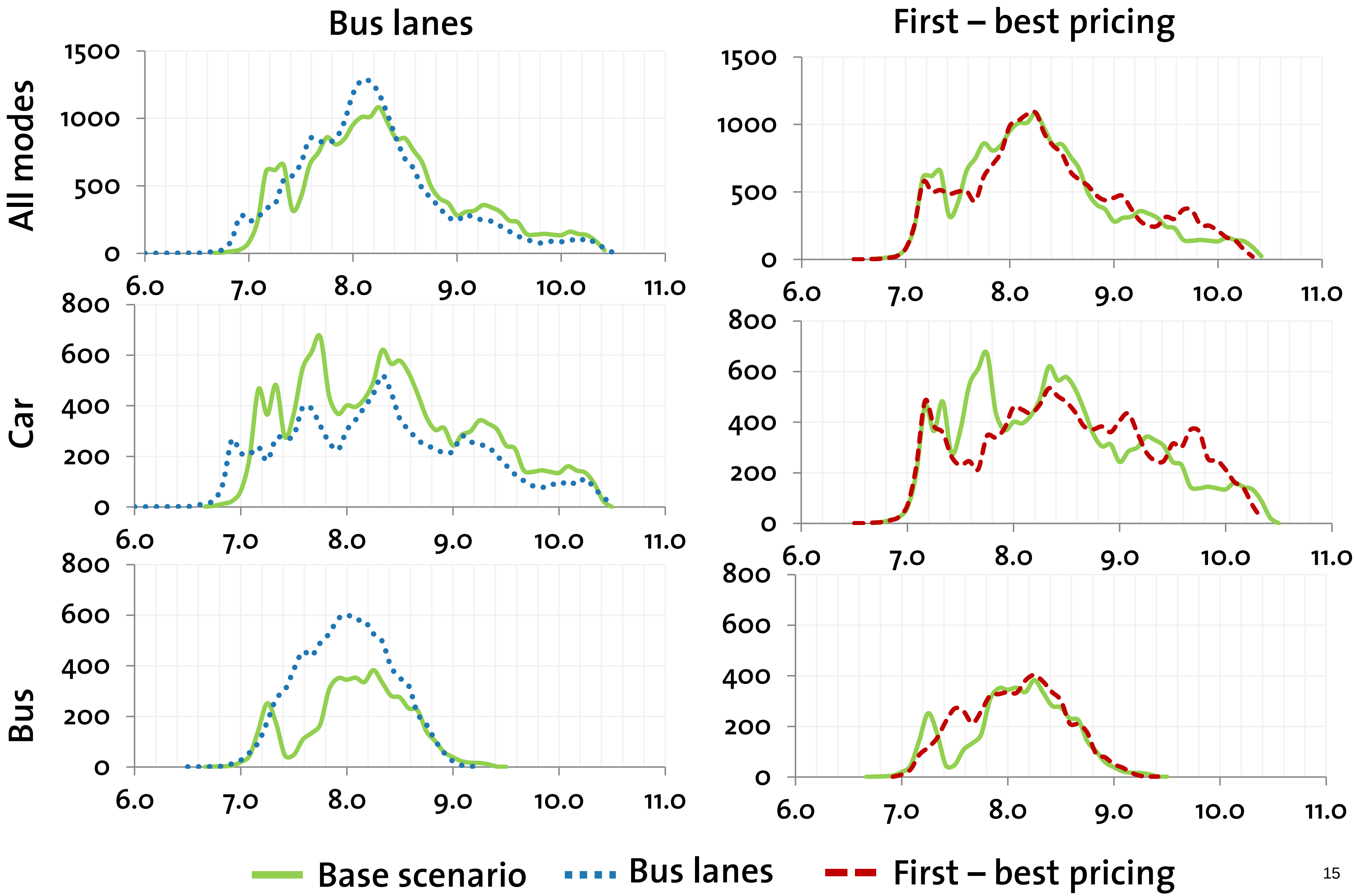
Buses are full during the peak hour - travelers have to wait for the next service
➔ benefit loss
Buses are too cheap or should run at even higher frequency?

Corridor – Bus Bunching

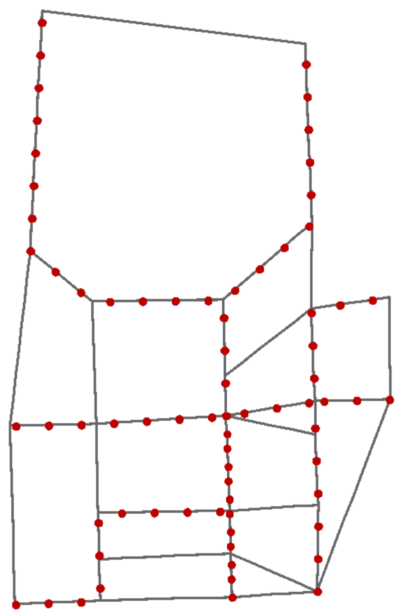


Significant bus bunching - running higher frequency might not be a solution

Corridor Departure Times – Morning peak



Extended Sioux Falls Scenario



Extended Sioux Falls Network with public transport according to Abdullal and LJ LeBlanc (1979)

- 817864 agents (10% captive pt riders)
- Distance between bus stops: 600m
- Bus frequency: 6 min
- Bus capacity: 90
- Bus length: 17.6m
- Dwell times: 1 sec

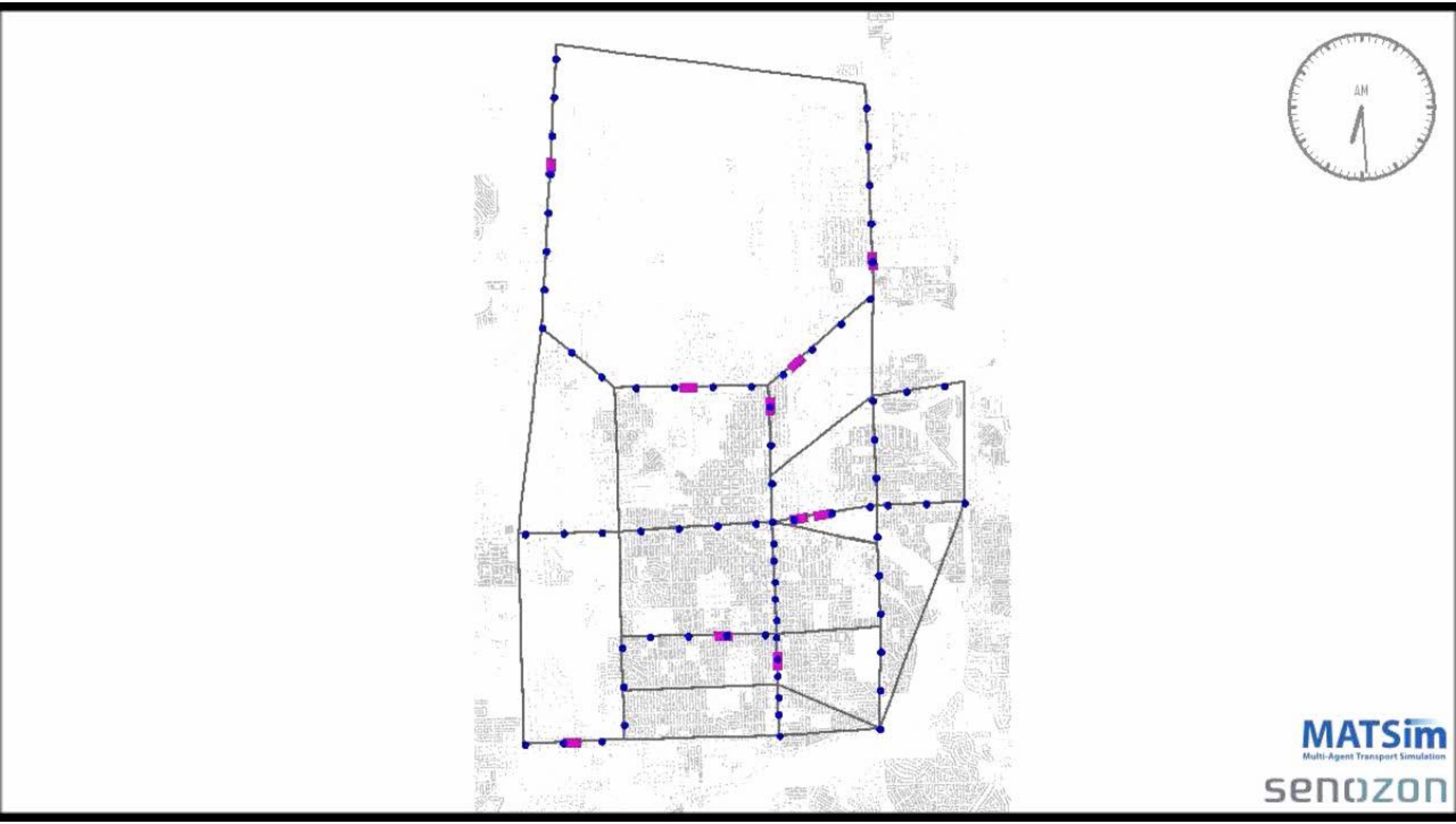
3 Scenarios:

Base scenario	2-3 mixed lanes
Bus lane scenario	1-2 car lanes 1 bus lanes
First-best road pricing	2-3 mixed lanes

Lane capacity: 510 – 1740 veh/h

Bus lane capacity: 90 * $\frac{60\ min}{6\ min}$= 900 pax/h

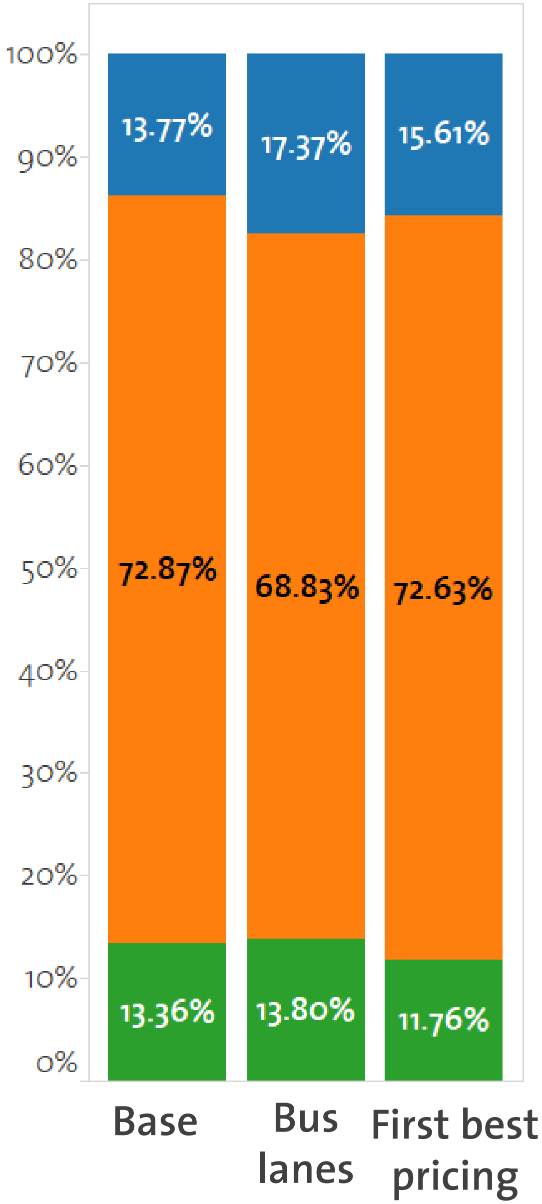
Sioux Falls Simulation



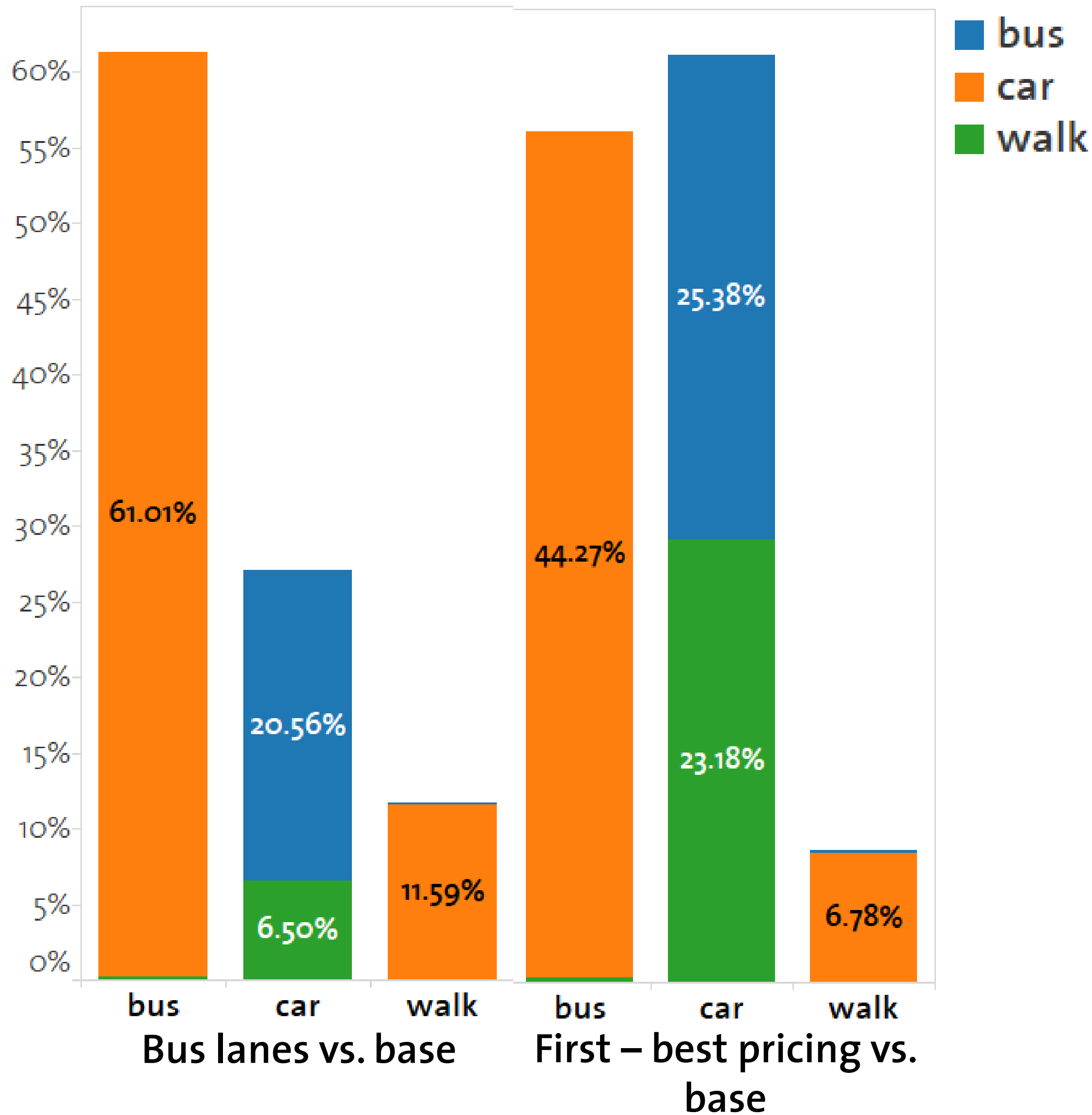
Sioux Falls Scenario – Key Numbers

	Base scenario	Bus lanes scenario	First – best pricing
Avg. Car Speed	21.41 km/h	24.29 km/h	31.51 km/h
Avg. Bus Speed	25.59 km/h	26.17 km/h	42.51 km/h
Avg. Journey Travel Time	39.55 min	40.87 min	27.12 min
Car	33. 99 min	35.17 min	18.73 min
Bus	58.39 min	55.59 min	51.48 min
Walk	50.42 min	50.72 min	46.50 min
Avg. In-vehicle Distance	8688 m	8518 m	8603 m
Car	10656 m	10765 m	10496 m
Bus	3201 m + (1547 m)	3277 m + (1480 m)	3366 m + (1503 m)
Walk	1931 m	1942 m	1786 m

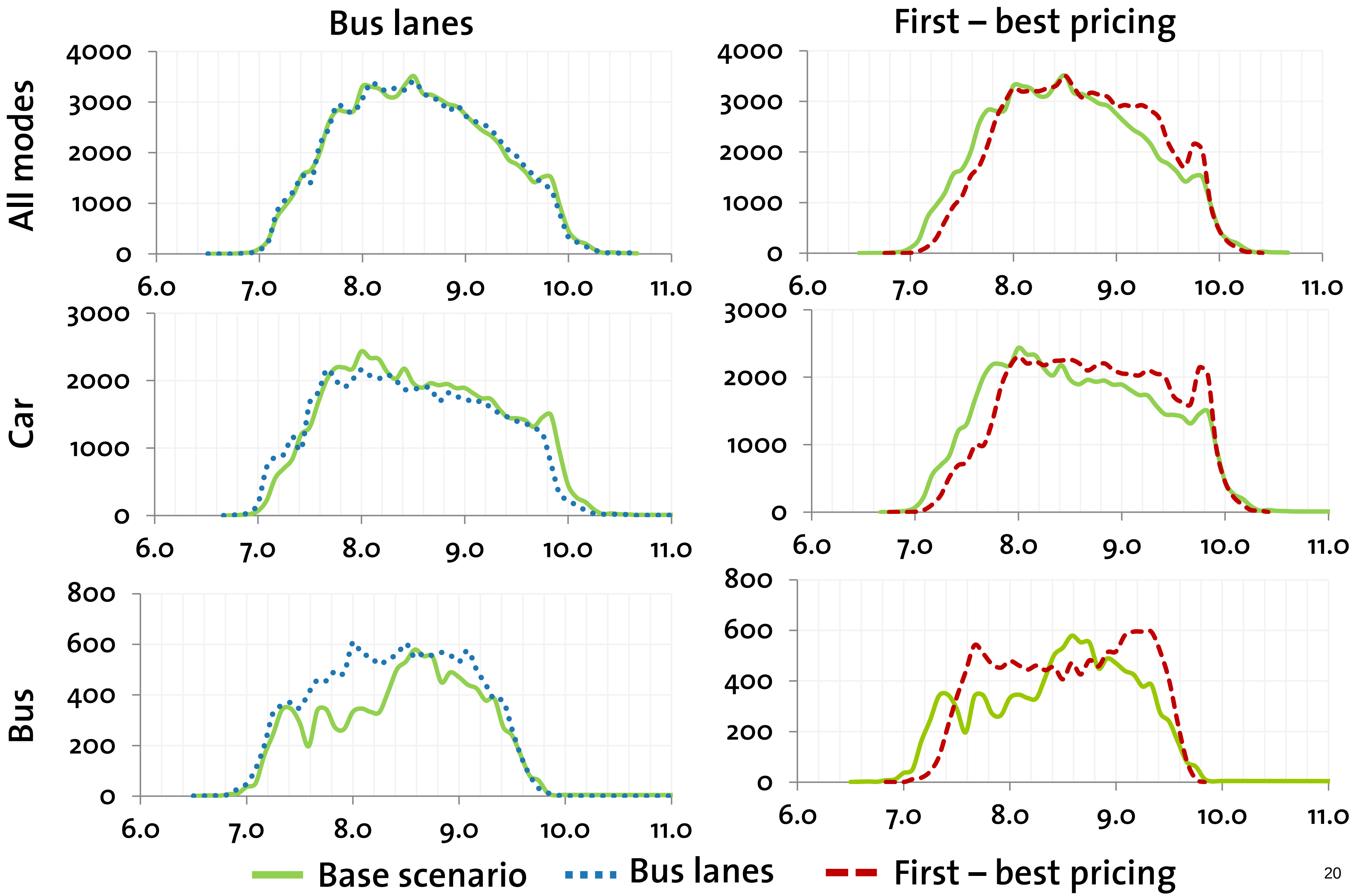
Sioux Falls – Mode share



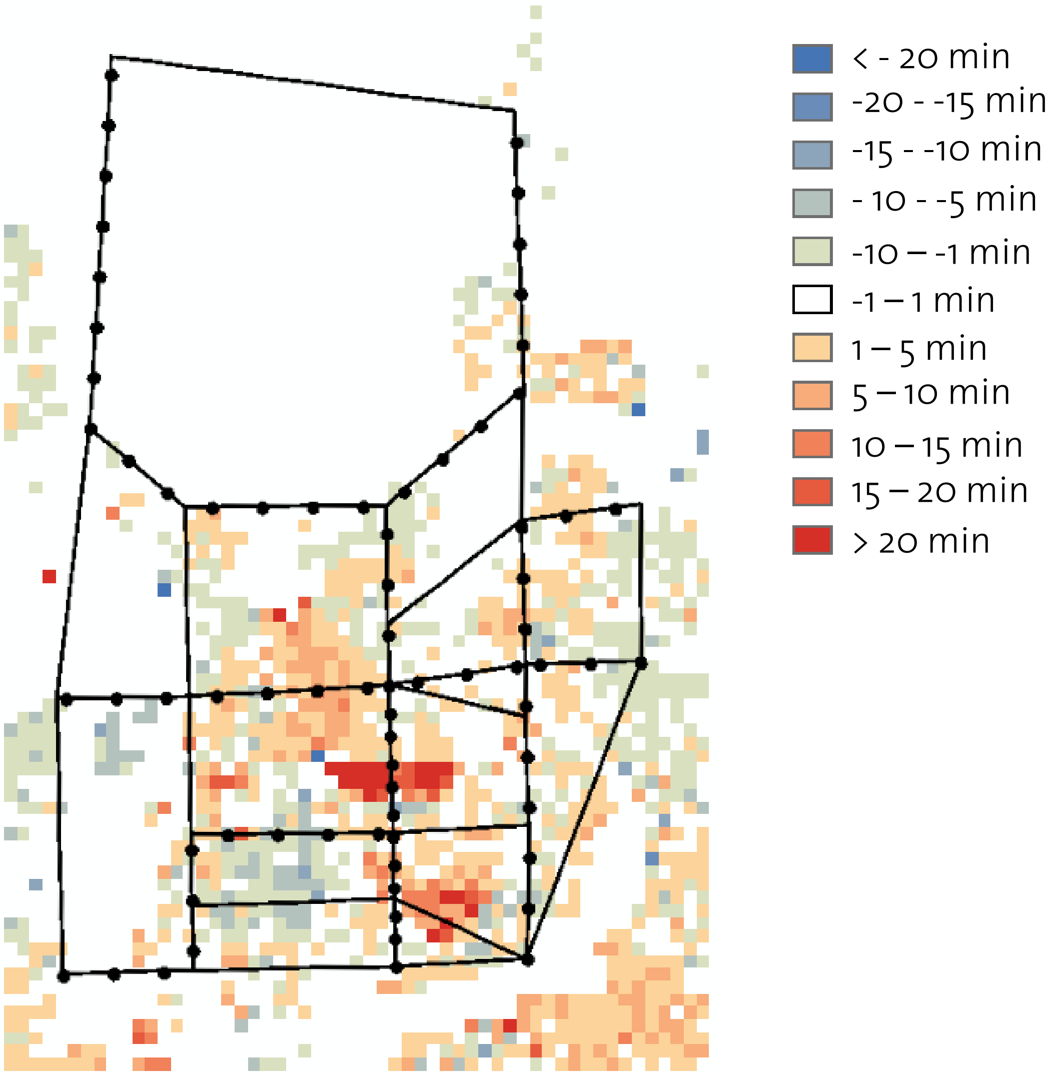
Where do the "mode switchers" come from?



Sioux Falls Departure Times – Morning peak



Sioux Falls – Spatial Distribution of Travel Time Changes



Travel time changes (home – work – home) in min according to home location

Conclusion

1. Introduction of bus lanes **increases avg. travel speed for car and buses**, but can decrease avg. travel time (mode switch from car to slower buses)
2. Bus lane achieves higher avg. speed predominantly through **mode shift**, where road pricing uses other dimensions as time choice, route choice
3. Based only on travel times bus lanes seems to have negative welfare effect, but lower congestion might have **positive effects not captured by the model**
   - More comfortable travel experience
   - Less accidents
   - Less pollution
4. Agent-based approach is **scalable** and allows to conduct cost-benefit analysis on the large scale networks
5. Classical welfare analysis in agent-based simulations remains challenging

Outlook

Can we trust these results?

- Need to determine confident intervals with various simulations using different random seeds
- Investigation of sensitivity to behavioral parameters
- Investigation of sensitivity to supply constrains (e.g. public transport fares, headways)
- Investigation of demand dependency (how much congestion and how many bus users per bus lane do we need to justify bus lanes?)

➔ **Computationally intensive tasks**

- Additional degree of realism (user heterogeneity, variable dwell times)
- Superposition of policies (road pricing and bus lanes)
- Would first-best pricing improve by incorporating delay caused to public transport users?