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Marginal Congestion Cost Pricing in a Multi-Agent Simulation

Ihab Kaddoura | TU Berlin | Konferenz „Verkehrsökonomik und -politik"

Berlin, 27.06.2014

Congestion Cost

External Costs = Cost which are not borne by the transport users
(e.g. Maibach et al., 2008)

External Congestion Cost: **Other** individuals' delay cost

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Motivation

Development of a methodology…

… for a simulation-based investigation of congestion cost.

… for a simulation-based optimization.

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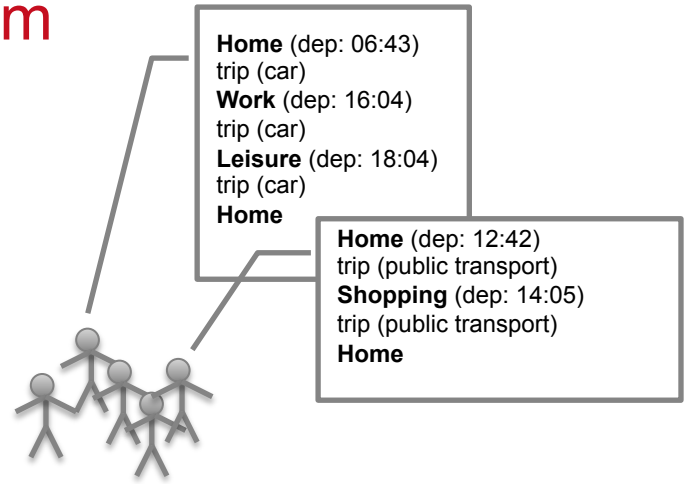
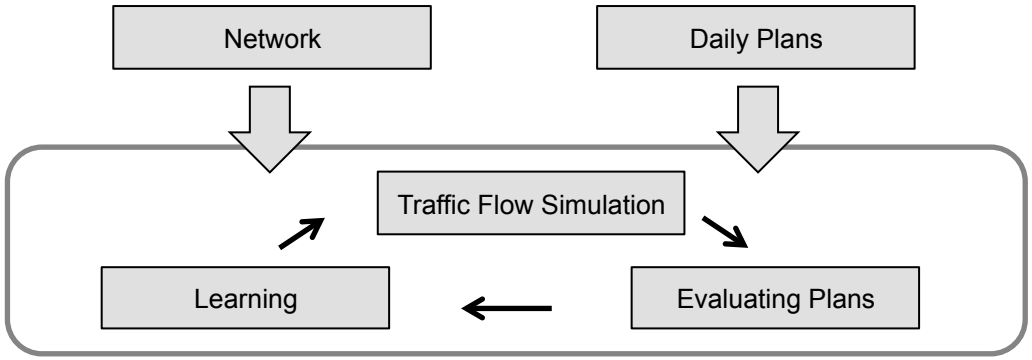
Transport simulation with MATSim





- Plan selection with respect to a multinomial logit model
- Plan modification according to choice dimensions (**Learning)**

Evaluating Plans

$$V_p = \sum_{i=1}^{n} \left(V_{perf,i} + V_{tr,i} \right)$$

- trips & activities

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Traffic Flow Simulation: Queue Model

- All agents simultaneously execute their plans and interact in the physical environment.

- Each link is modeled as *First In First Out* queue with three attributes:
  - free speed travel time t_{free}
  - flow capacity c_{flow}
  - storage capacity $c_{storage}$

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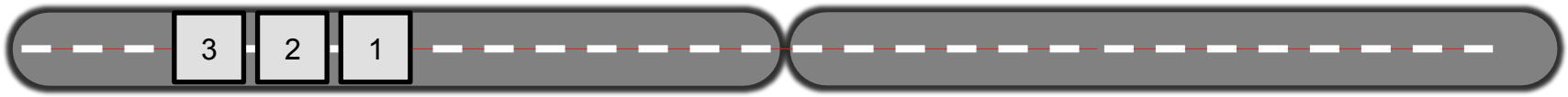
Example

Example

t = 0

c_{flow} = 1200 veh/h



Agent	delay
1	0 sec
2	0 sec
3	0 sec

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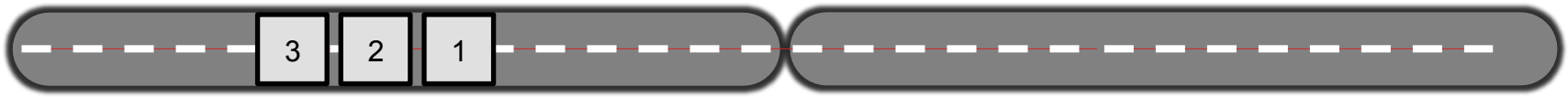
Example

t = 1

c_{flow} = 1200 veh/h



Agent	delay
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2	0 sec
3	0 sec

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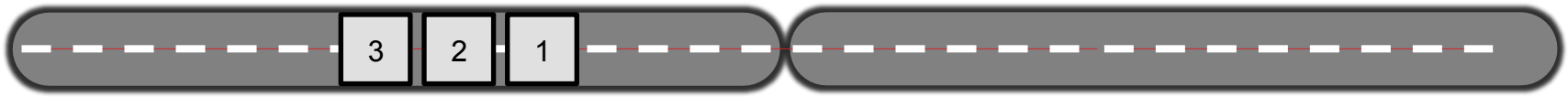
Example

t = 2

c_{flow} = 1200 veh/h



Agent	delay
1	0 sec
2	0 sec
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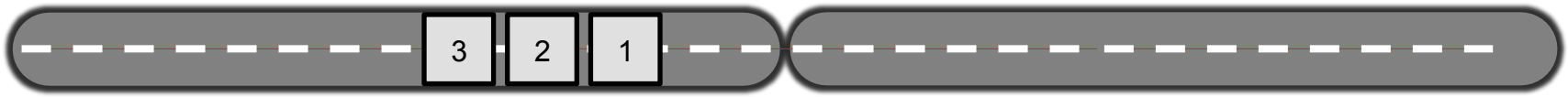
Example

t = 3

c_{flow} = 1200 veh/h



Agent	delay
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2	0 sec
3	0 sec

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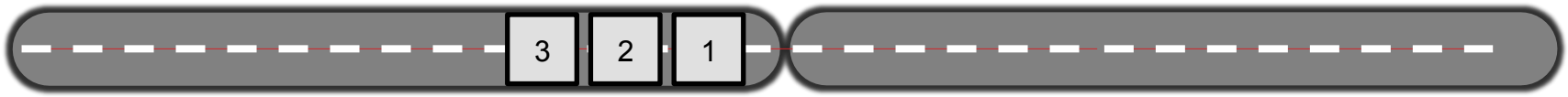
Example

t = 4

c_{flow} = 1200 veh/h



Agent	delay
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2	0 sec
3	0 sec

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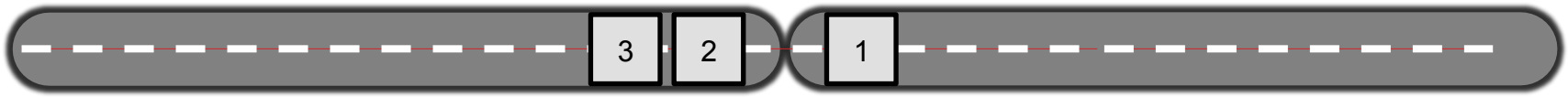
Example

t = 5

c_{flow} = 1200 veh/h



Agent	delay
1	0 sec
2	0 sec
3	0 sec

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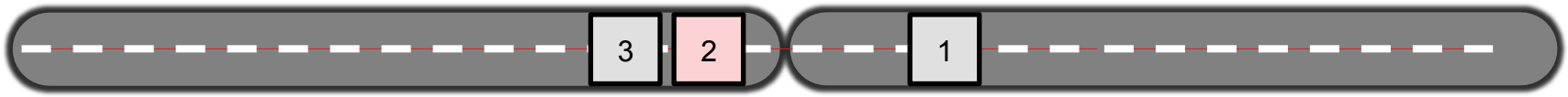
Example

t = 6

c_{flow} = 1200 veh/h



Agent	delay
1	0 sec
2	1 sec
3	0 sec

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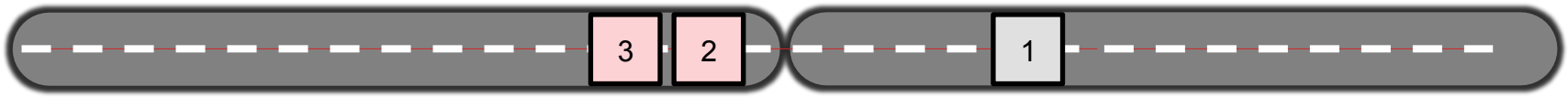
Example

t = 7

c_{flow} = 1200 veh/h



Agent	delay
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2	2 sec
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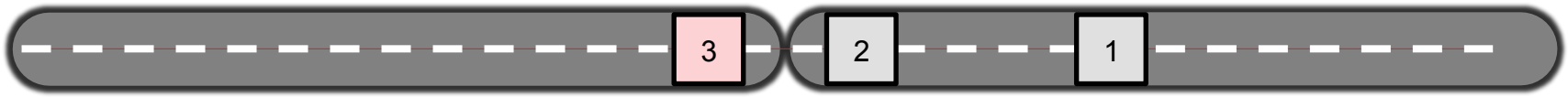
Example

t = 8

c_{flow} = 1200 veh/h



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3	2 sec

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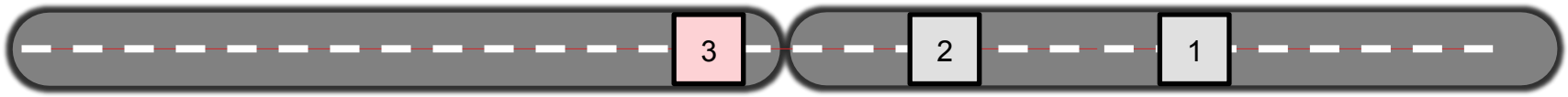
Example

t = 9

c_{flow} = 1200 veh/h



Agent	delay
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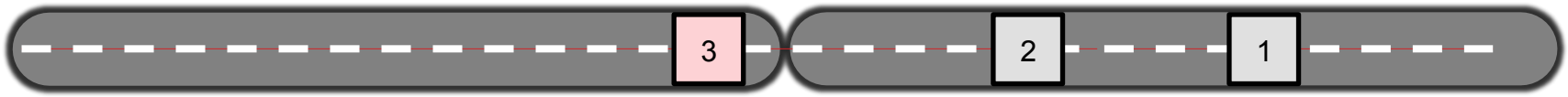
Example

t = 10

c_{flow} = 1200 veh/h



Agent	delay
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2	2 sec
3	4 sec

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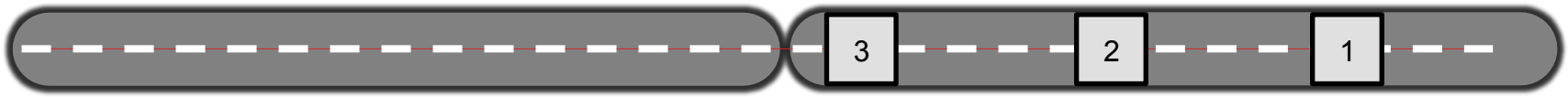
Example

t = 11

c_{flow} = 1200 veh/h



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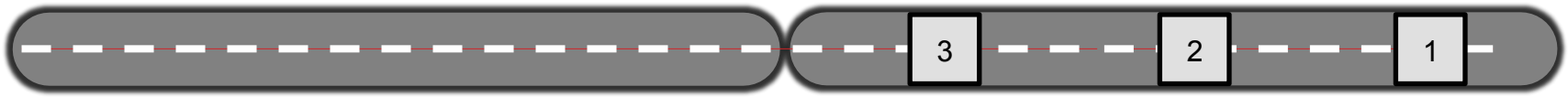
Example

t = 12

c_{flow} = 1200 veh/h



Agent	delay
1	0 sec
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Example – Marginal Congestion Cost Pricing

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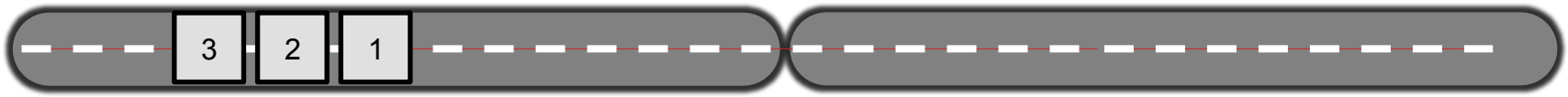

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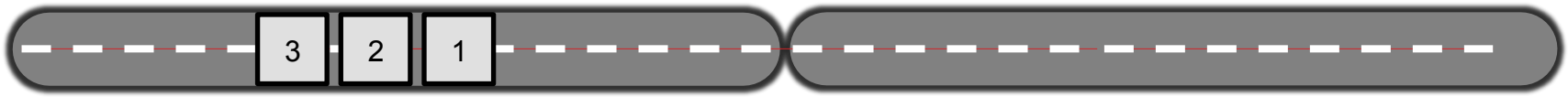

Agent	delay affected	delay caused
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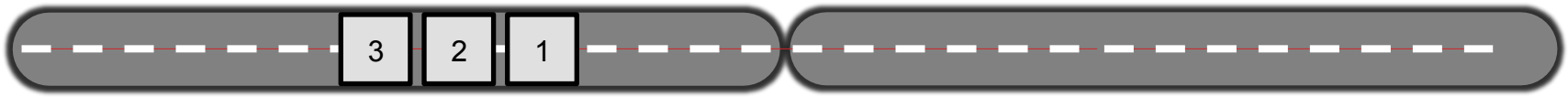
Example

t = 2

c_{flow} = 1200 veh/h



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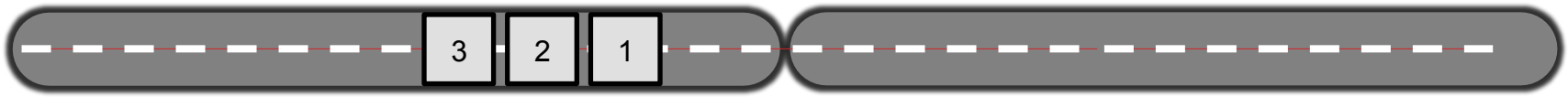

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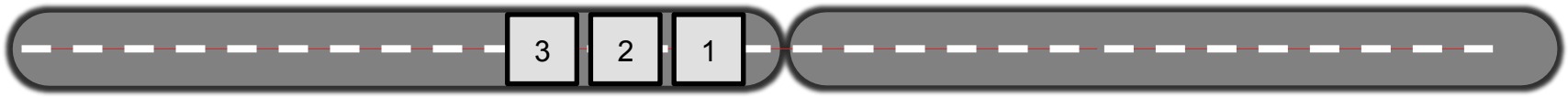

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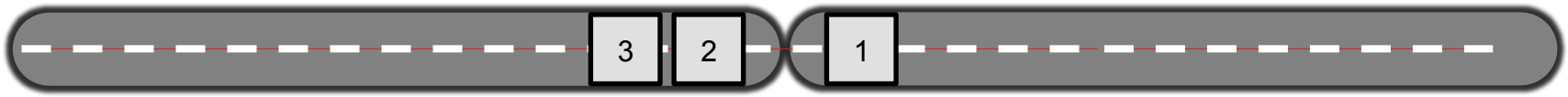

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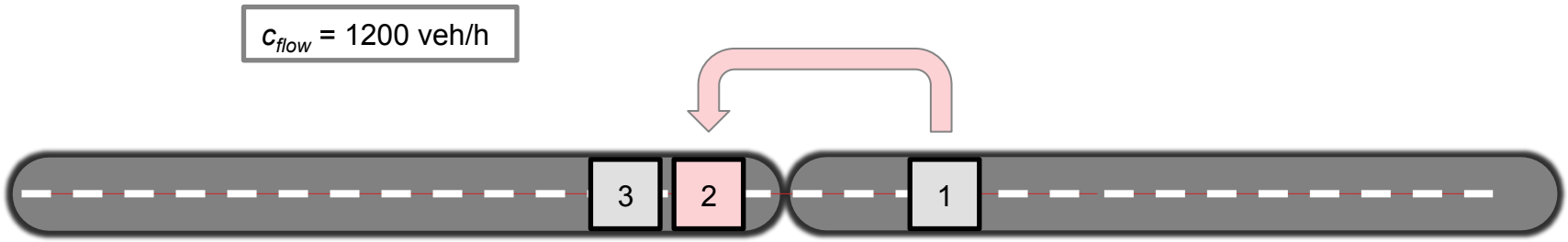

Agent	delay affected	delay caused
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3	0 sec	0 sec

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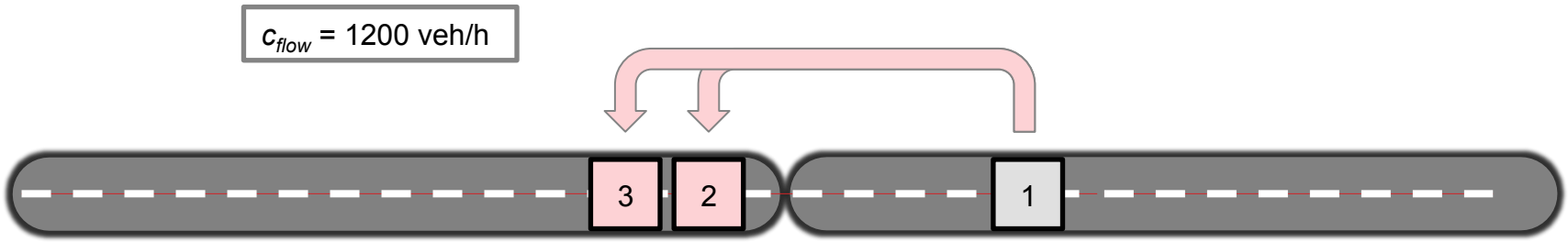

Agent	delay affected	delay caused
1	0 sec	3 sec
2	2 sec	0 sec
3	1 sec	0 sec

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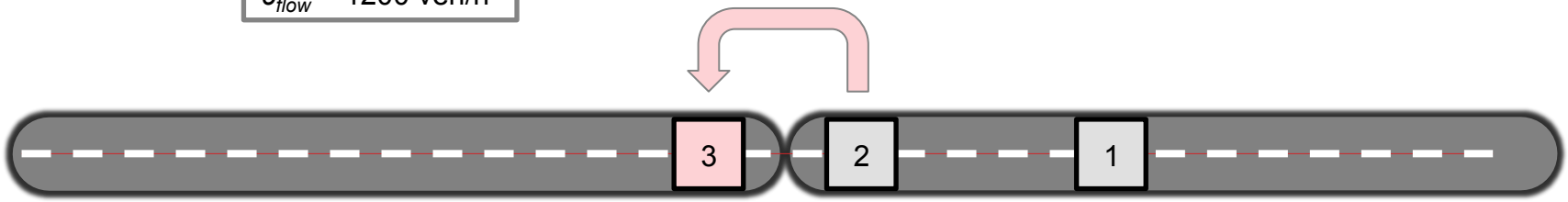

Agent	delay affected	delay caused
1	0 sec	3 sec
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3	2 sec	0 sec

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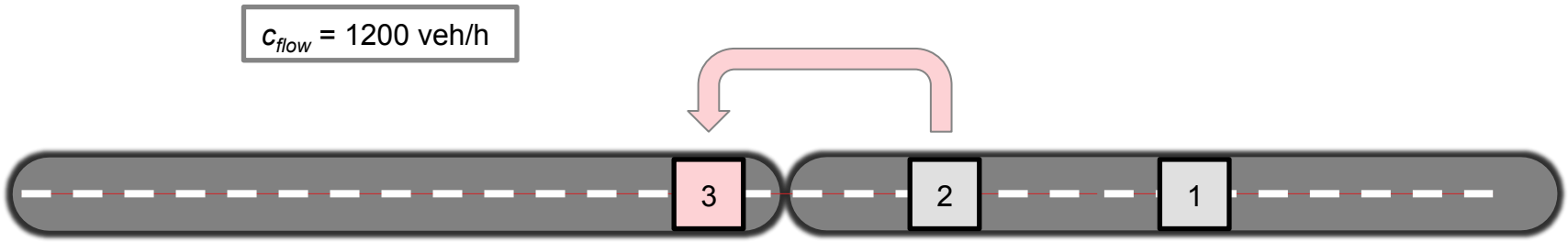
Example

t = 9



Agent	delay affected	delay caused
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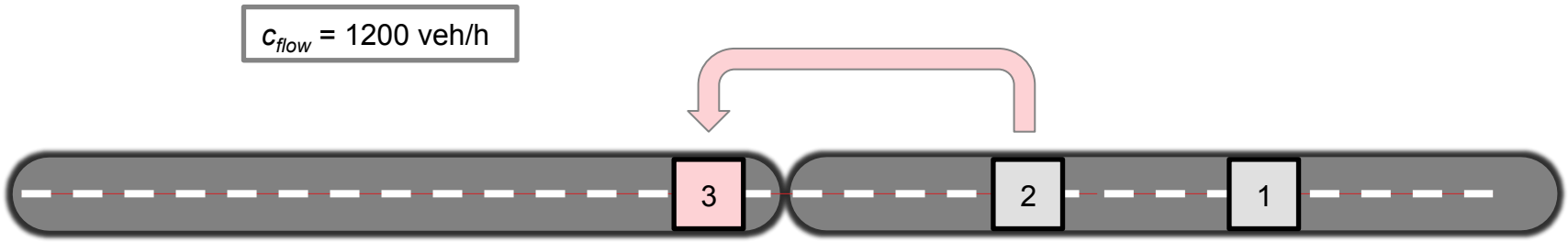
Example

t = 10



Agent	delay affected	delay caused
1	0 sec	3 sec
2	2 sec	3 sec
3	4 sec	0 sec

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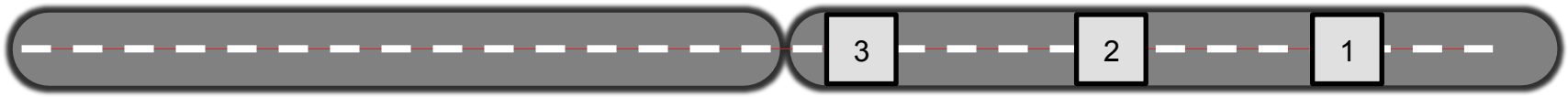
Example

t = 11

c_{flow} = 1200 veh/h



Agent	delay affected	delay caused
1	0 sec	3 sec
2	2 sec	3 sec
3	4 sec	0 sec

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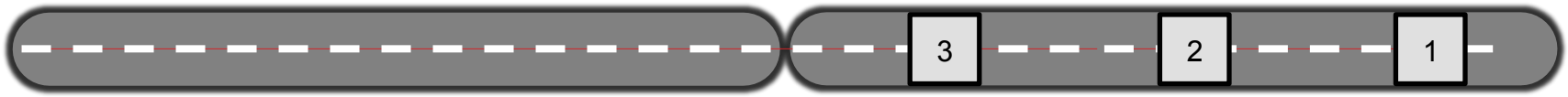
Example

t = 12

c_{flow} = 1200 veh/h



Agent	delay affected	delay caused
1	0 sec	3 sec
2	2 sec	3 sec
3	4 sec	0 sec

→ €€€

→ €€€

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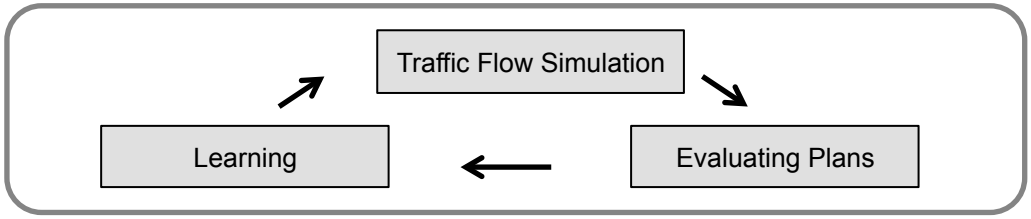
Agent-based marginal congestion cost pricing

- Agent-based and dynamic computation of delay effects imposed on other individuals
- Conversion into user-specific and dynamic tolls



- Adaptation of travel decisions based on internal and external congestion cost

- Consideration of monetary payments, i.e. congestion costs in each individual's utility

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Berlin Scenario

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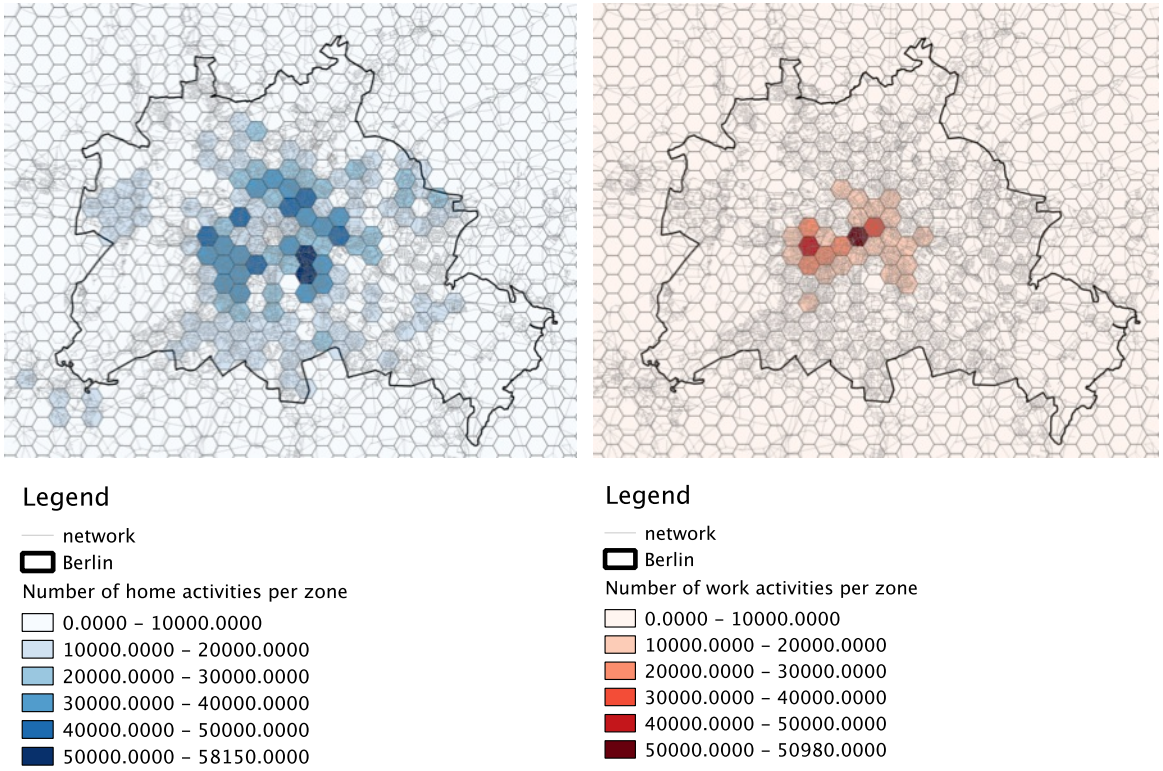
Scenario Setup

- generated by A. Neumann, M. Balmer and M. Rieser (Neumann et al., 2014)
- contains all major and minor roads (2008)
- calibrated with regard to the mode shares, travel times and distances



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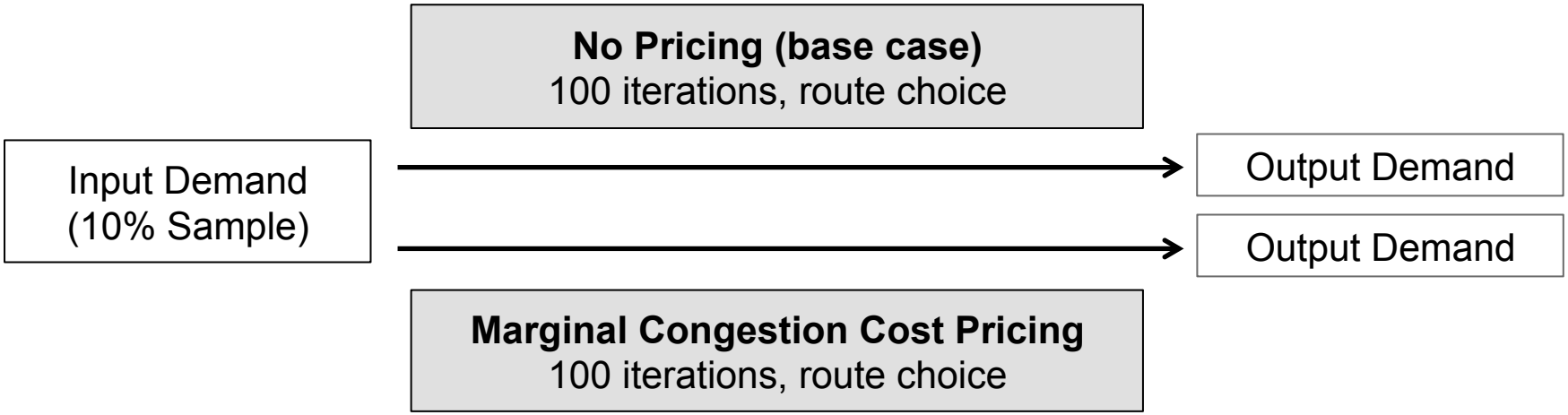
Simulation Experiments



Average Congestion Cost (base case)

The congestion cost imposed on other users vary by …

… **time** (10 – 10.15 a.m.: 16 sec per car trip // 3 – 3.15 p.m.: 111 sec per car trip)

… **trip length** (4.5 – 5 km: 11 sec per car trip // 10.5 – 11 km: 24 sec per car trip)

Who causes the highest congestion cost?
Who is affected by the highest congestion cost?

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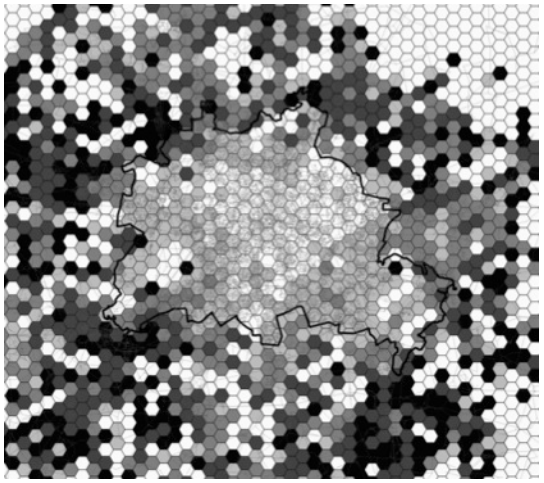
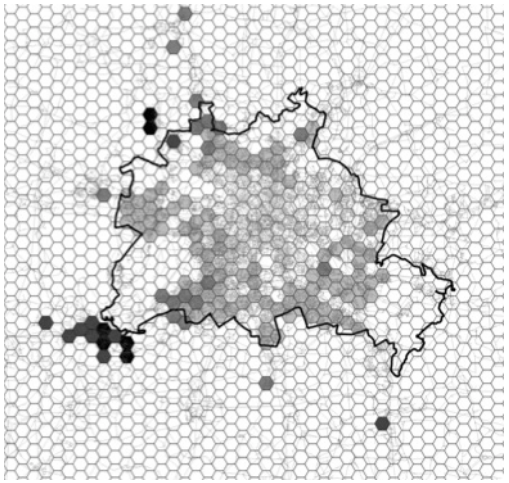
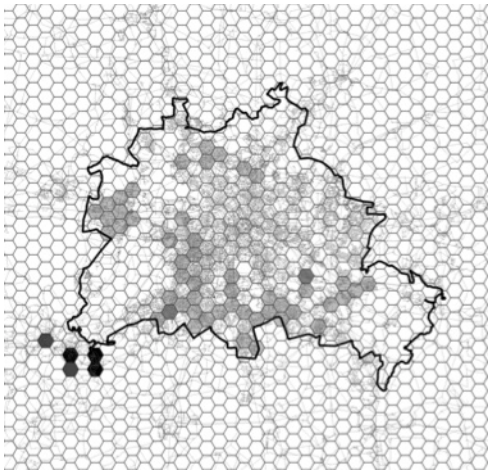
Spatial analysis (base case)



all zones



zones with more than 5000 residents

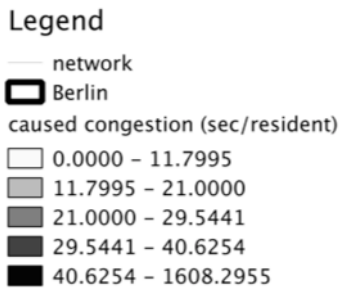


zones with more than 10000 residents

Average congestion cost per resident mapped back to the home location of the causing agent

→ high avg. congestion cost: residents in the area outside of Berlin

→ high avg. congestion cost AND absolute relevant cost: Potsdam, southern suburbs



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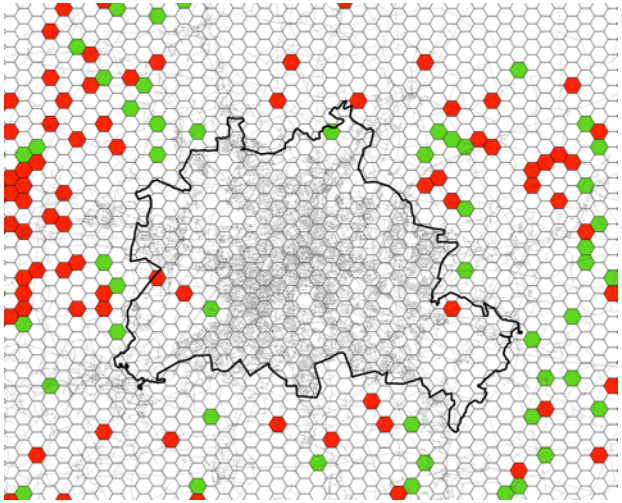
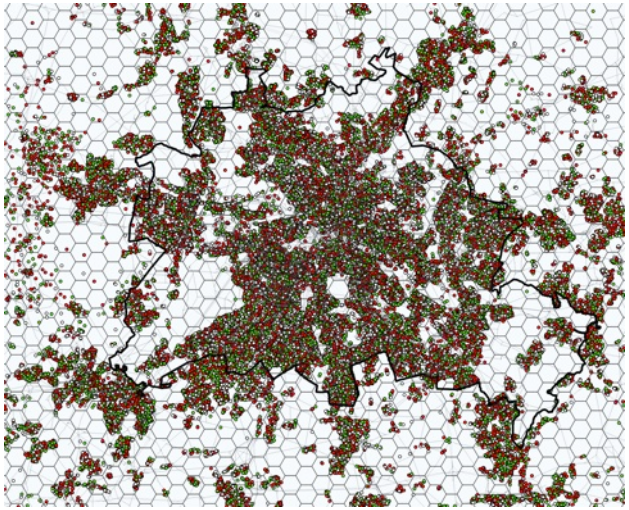
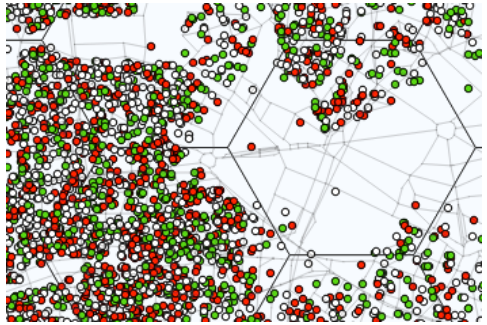
Caused vs. affected congestion cost (base case)

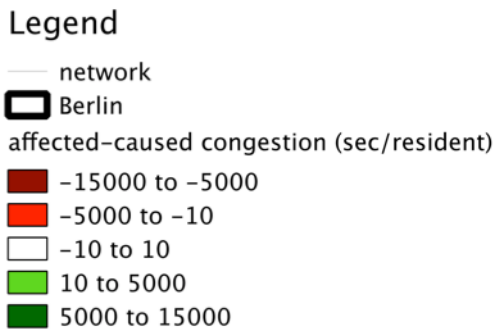






Aggregated analysis (Comparison of the averages for each zone)

→ avg. caused and avg. affected delays approx. on the same level (+/- 10 sec)



Agent-specific analysis

→ avg. absolute difference per agent: 30 sec

→ standard deviation: 322 sec

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Base case vs. Marginal Congestion Cost Pricing

	No Pricing	Pricing	Difference
total travel time (car mode)	1 422 720 h	1 409 071 h	**- 13 649 h**
avg. travel time per car trip	1 076 sec	1 065 sec	**- 11 sec**
avg. delay per car trip	102 sec	91 sec	**- 11 sec**

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Conclusion

Successful development of a simulation-based approach to calculate external congestion cost…

… which allows for a user-specific and dynamic optimization of road pricing.

The results can be used to evaluate other measures…
… or to derive more practicable pricing schemes.

References

Maibach, M., D. Schreyer, D. Sutter, H. van Essen, B. Boon, R. Smokers, A. Schroten, C. Doll, B. Pawlowska, and M. Bak. Handbook on estimation of external costs in the transport sector. Technical report, CE Delft, 2008.

Neumann, A., M. Balmer, and M. Rieser. Converting a Static Trip-Based Model Into a Dynamic Activity- Based Model to Analyze Public Transport Demand in Berlin. In Roorda, M. and E. Miller, editors, *Travel Behaviour Research: Current Foundations, Future Prospects*, chapter 7, pages 151–176. Inter- national Association for Travel Behaviour Research (IATBR), 02 2014. ISBN 9781304715173.

Acknowledgements

Thanks to…

… Kai Nagel

… Benjamin Kickhöfer

… Lars Kröger