Dipl. Inf-Ing. Marcel Rieser, rieser@vsp.tu-berlin.de

Modal Split under the Influence of Road Pricing Measures

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Technische Universität Berlin

MATSim
Multi-Agent Transport Simulation

This research

- Goal: Simulate changes in the modal split, when the pricing for the different modes of transport changes. E.g.:
  - making public transit cheaper
  - making individual car traffic more expensive

- Approach:
  - simulate base case scenario
  - simulate toll scenario
  - compare the two scenarios

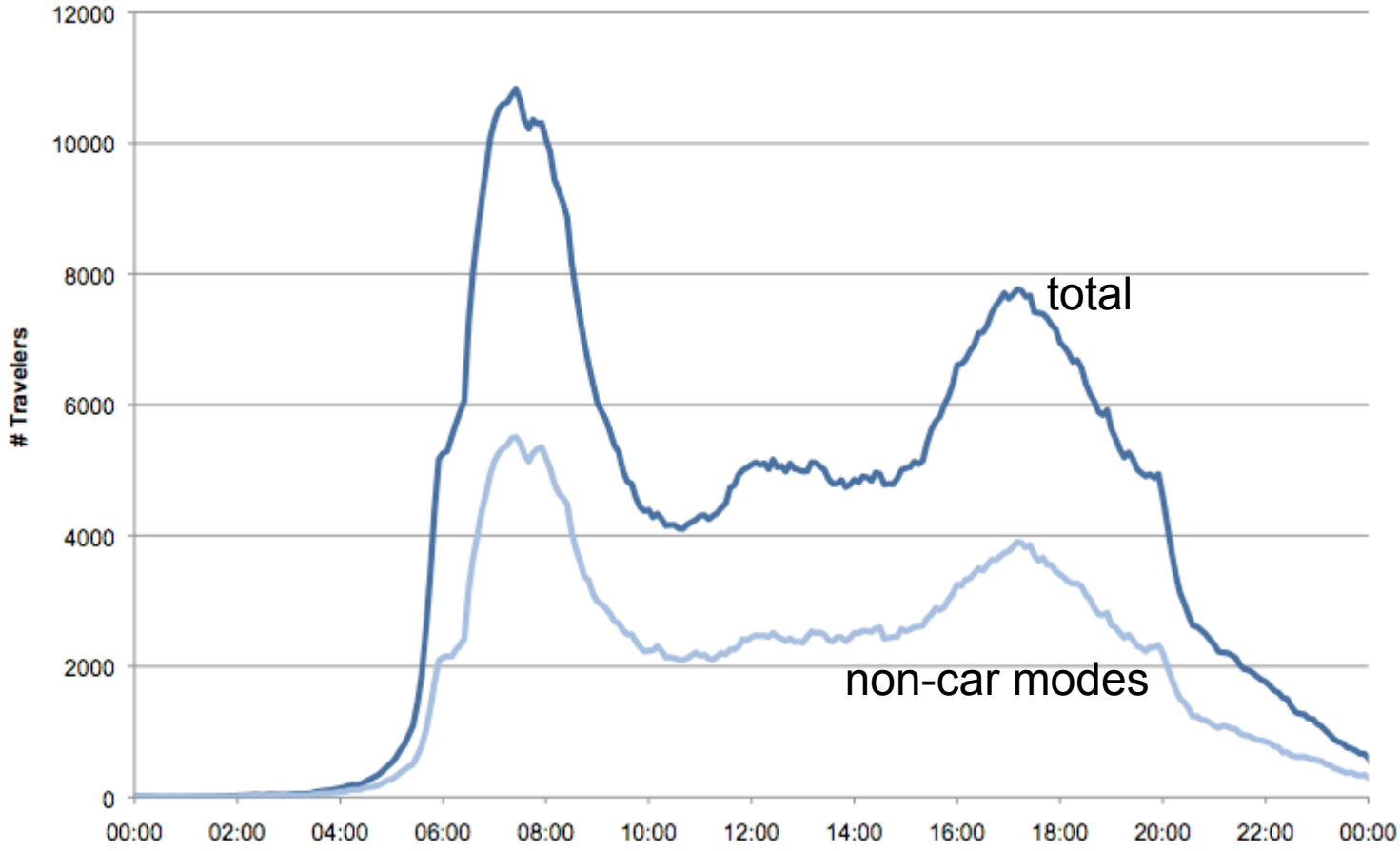
- Still in the early stages, with simple examples / applications only as “proof of concept”

Scenario

- 10% of the people traveling through the area of Zurich
  ≈ 180k agents
- Complete daily activity chains
- Agents can decide to either use **car** or to use **non-car** (public transit, …) as transportation mode for a day.
- Agents tend to use the transportation mode that has higher utility for them.

Base Case: Travel Volumes

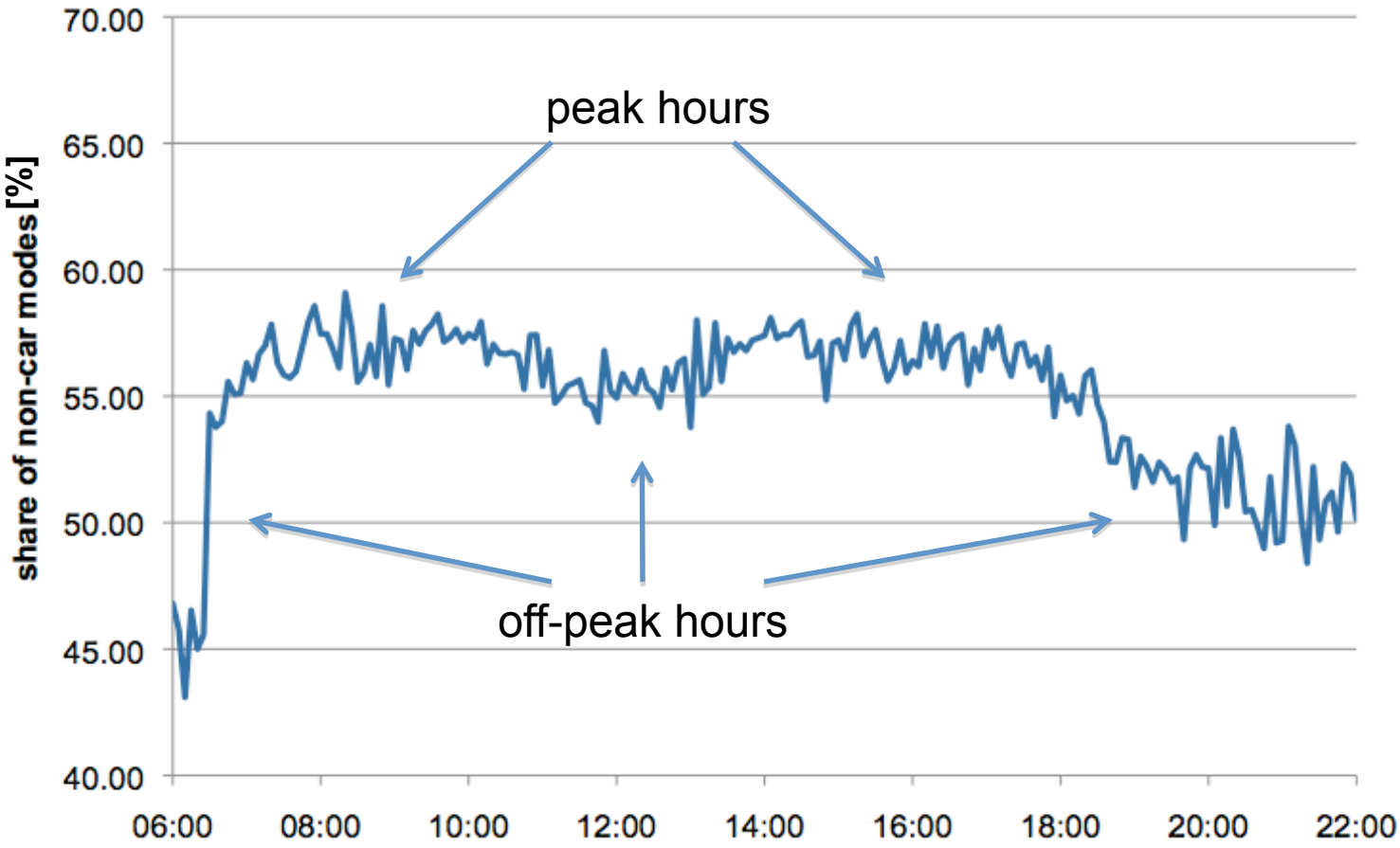
- Typical morning and evening peaks



MATSim
Multi-Agent Transport Simulation

Base Case: Modal Split

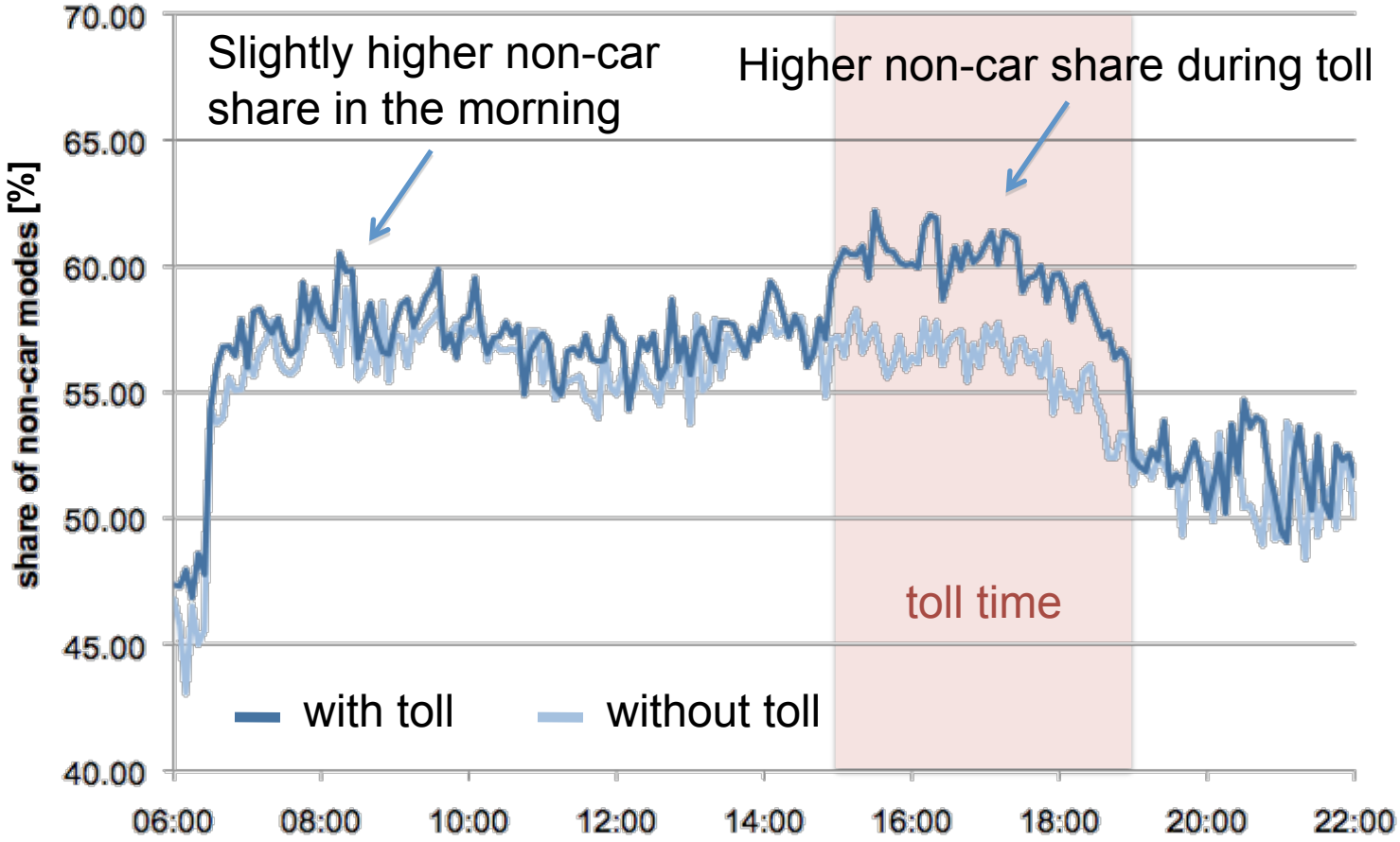
- Time-dependent mode share



MATSim
Multi-Agent Transport Simulation

Toll Case / Comparison

- Distance toll 50 ct/km from 15:00 to 19:00 in city of Zurich



MATSim
Multi-Agent Transport Simulation

Conclusion

- In the toll case, more agents decide to use non-car mode → as was to be expected
- Fully time-dependent reaction
- reaction carries over to non-toll time

- So much about the “short version”.
  But how did we do that?
  What’s the concept of our simulation that enables us to do such simulations?

MATSim Internals

Agenda / Remainder of this talk

What this talk is **not** about:

data, results

What this talk **is** about:

conceptual aspects to achieve the presented results

Data/Results are only shown as explanatory examples with limited real-world liability.

MATSim

Multi-Agent Transport Simulation

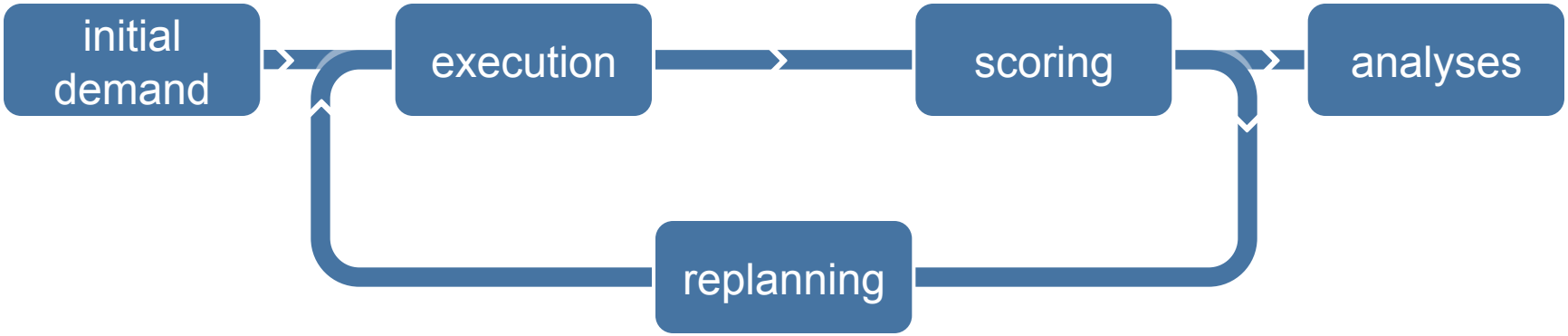
- Agents have complete daily schedules (“plans”) based on activity chains (e.g. home – work – shop – home)
- Agents can have multiple plans
- Agents can create new plans by modifying existing ones (e.g. modifying route or activity durations)
- Transport simulation executes one (selected) plan of each agent simultaneously
- Agents score the executed plan with a utility function
- Perform multiple iterations of modifying, executing and scoring plans

MATSim Keywords

- Population → Agents
- Demand → Plans
- Modifying Plans → Replanning
- Transport Simulation → (Plans) Execution
- Scoring Plans → Scoring

MATSim Simulations

- Iterative Process / Evolutionary Algorithm



Initial Demand

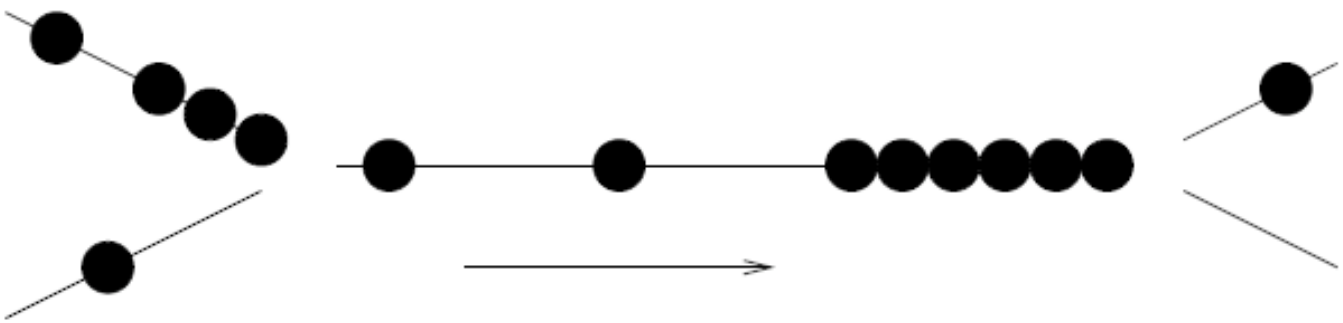
- Take whatever data is available and useful
- Preliminary mode, route, departure time choice
- Cannot easily be standardized because of available data
- Typical output:

```
<person id="241">
 <plan score="123">
     <act type="home" link="5834" end_time="07:00" />
     <leg mode="car" trav_time="00:25">
        <route>1932 1933 1934 1947</route>
     </leg>
     <act type="work" link="5844" dur="09:00" />
     <leg mode="car" trav_time="00:14">
        <route>1934 1933</route>
     </leg>
     <act type="home" link="5834" />
 </plan>
</person>
...
```

MATSim
Multi-Agent Transport Simulation

Plans Execution / Transport Simulation

- Transport simulation moves agents along the routes stored in plans
- Links are modeled as FIFO-Queues (“Hourglass”)
  Vehicles move on link with free speed until they hit queue; queue is served first come first serve according to capacity.



Important: Link can be full (spillback)

Plans Execution Output

- Simulation provides “events”

```
TIME       AGENT   TYPE        LINK
07:00:00   241     departure   5834
   ...     // other events
07:01:21   241     leaveLink   5834
   ...     // other events
07:21:33   241     enterLink   5834
   ...     // other events
07:22:54   241     arrival     5844
   ...
```

- Non-aggregated values
- Can be used for analyses

Scoring Plans

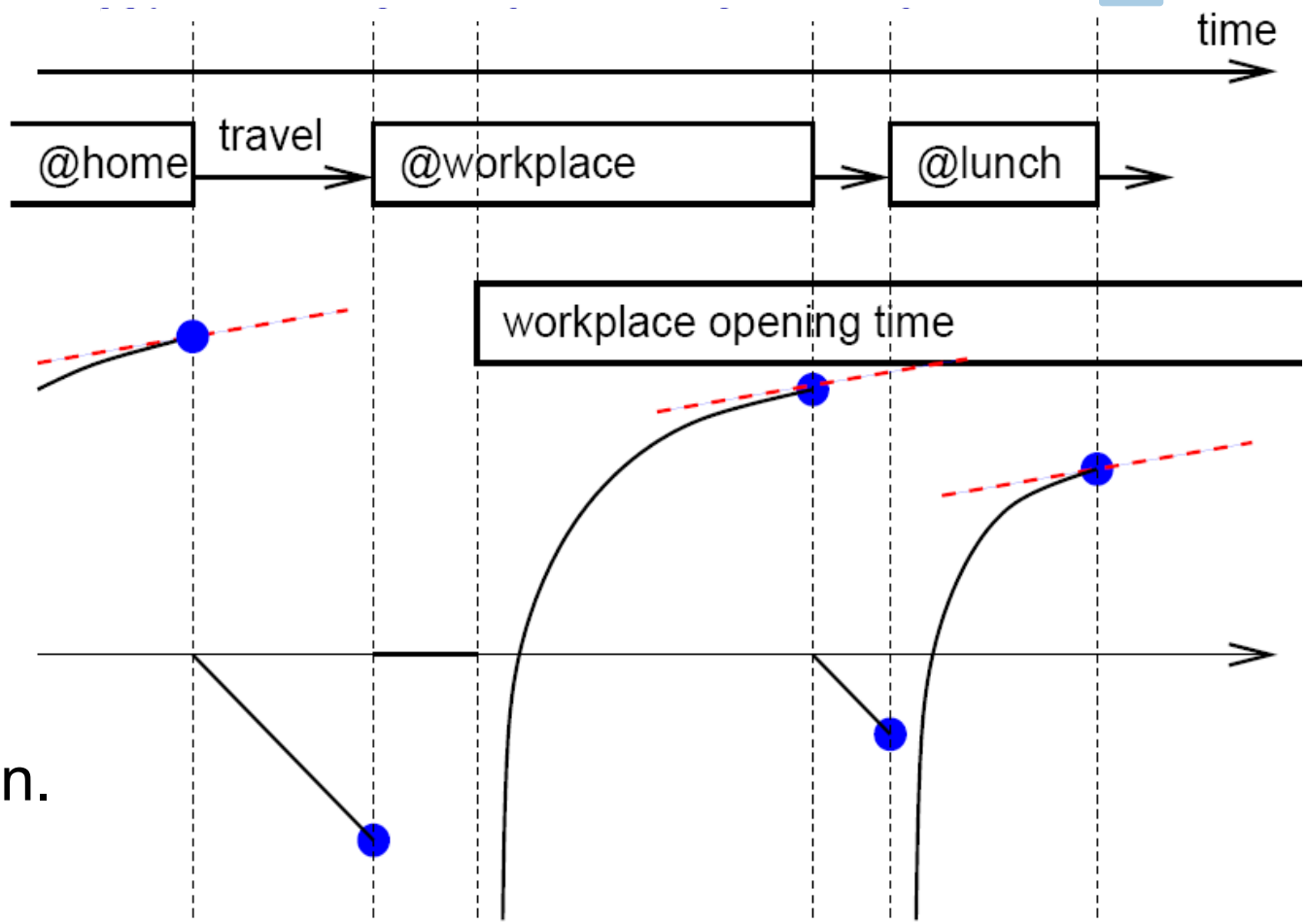
- Utility function to calculate the utility ("score") of an executed plan (complete day!)

$$U_{total} = \sum_{i=1}^{n} U_{perf,i} + \sum_{i=1}^{n} U_{late,i} + \sum_{i=1}^{n} U_{travel,i}$$

- Logarithmic form for positive utility for performing an activity
- Linear form for negative utility for time spent traveling or time being late
- Information about times extracted from events

Scoring Plans: Example

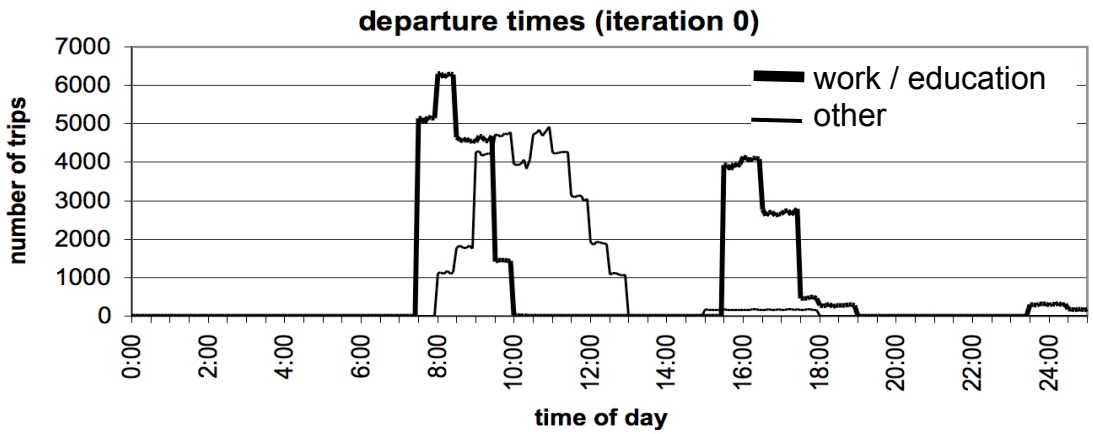
- Blue dots = values that are added up.
- Marginal utilities (red) need to be same at optimal solution.



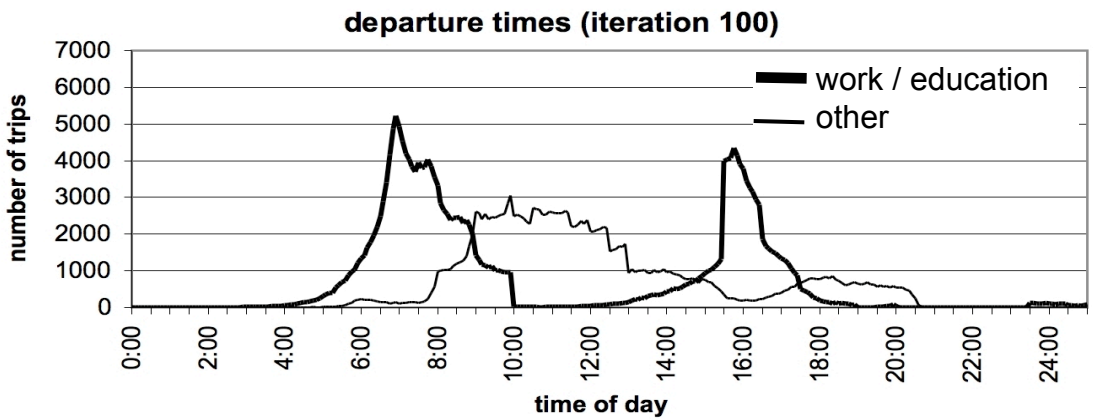
Replanning

- Agents can create new plans by modifying existing plans
  - modify route
  - modify activity durations
  - (modify transportation mode)
  - (modify secondary activities' location)
  - …
- Agents can decide to select existing plan with no modification
  - choose a random plan
  - choose best plan
  - choose random plan, but prefer good plans ("logit")
  - …

Replanning and Scoring



Iteration 0



Iteration 100

departures to non-work/non-education activities avoid rush hours

MATSim
Multi-Agent Transport Simulation

Adding Tolls to MATSim

Adding Tolls to MATSim

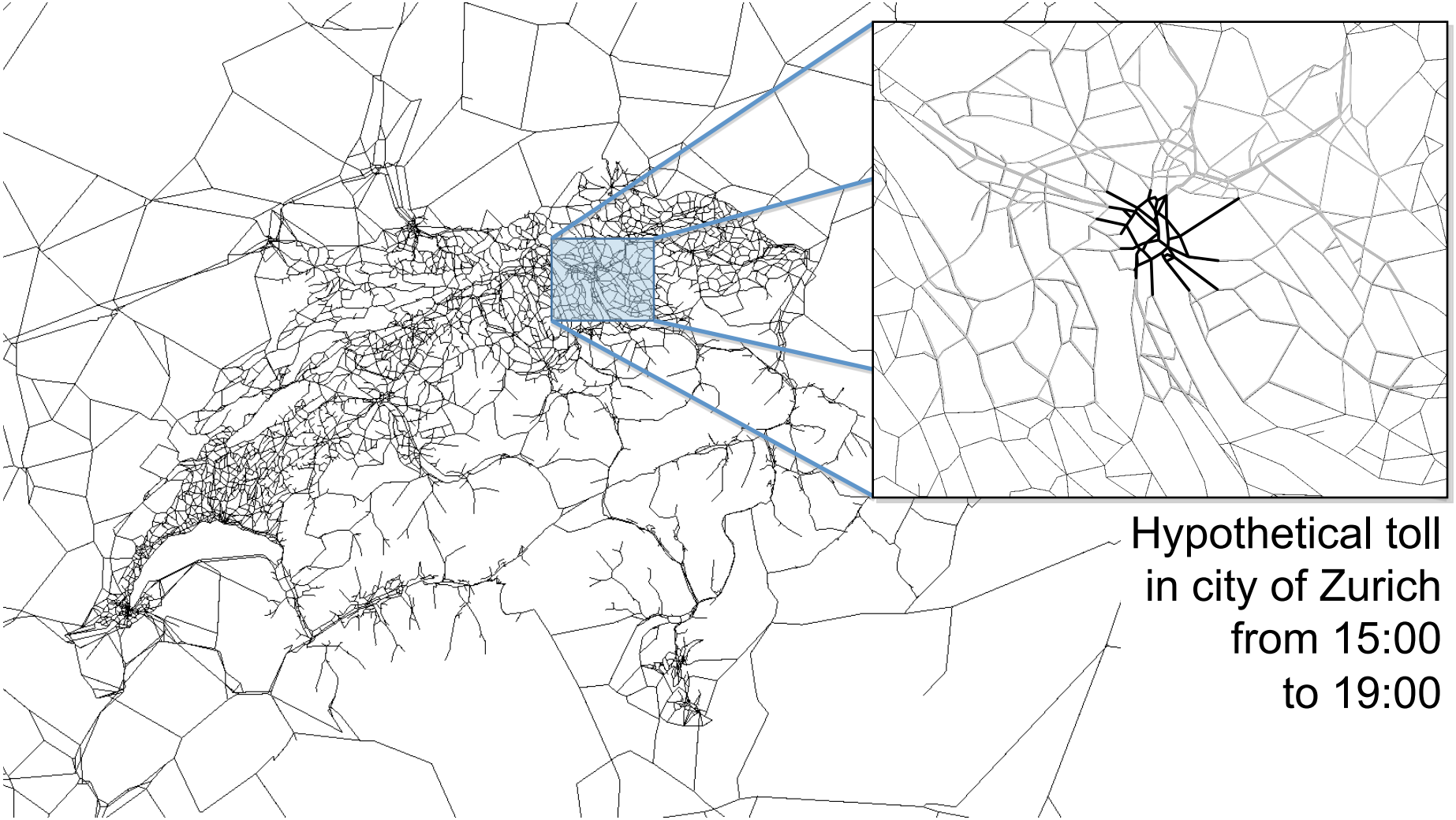
- Extend the utility function:

$$U_{total} = \sum_{i=1}^{n} U_{perf,i} + \sum_{i=1}^{n} U_{late,i} + \sum_{i=1}^{n} U_{travel,i} + U_{tolls\ paid}$$

- Events give information about agents traveling along tolled links
- Tolls are just one part of the total (dis)utility

- Following example simulates commuter traffic only without mode choice (car-only)

Example: Time-dependent Toll



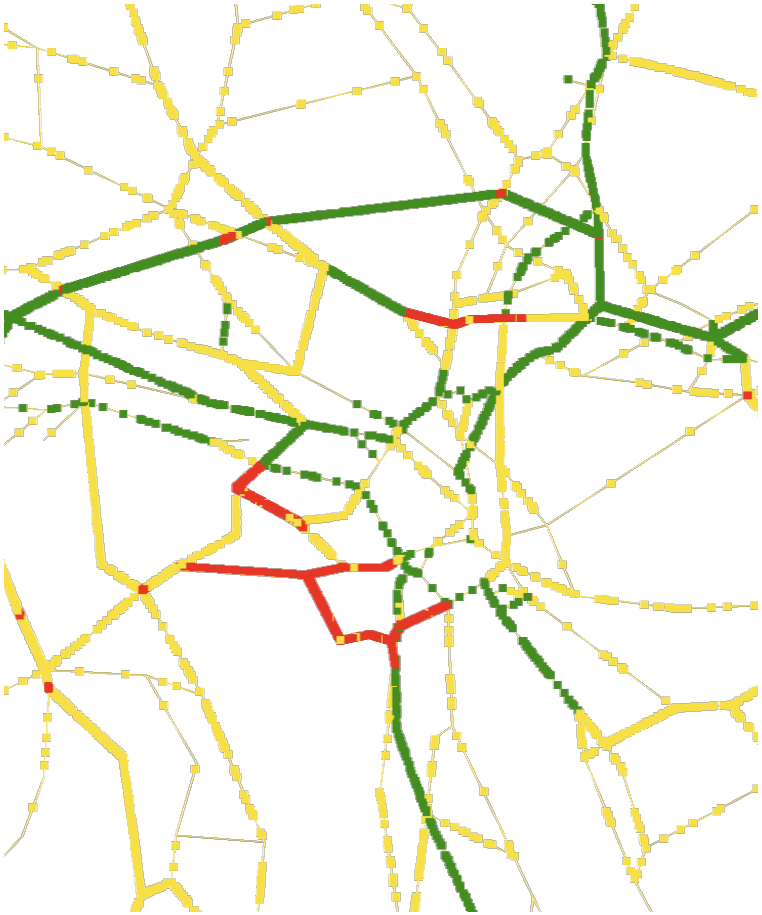
Hypothetical toll
in city of Zurich
from 15:00
to 19:00

MATSim
Multi-Agent Transport Simulation

Example: Time-dependent Toll

- Evening Traffic (17:30)

base case: no traffic jams



toll case: traffic jams outside toll area

MATSim
Multi-Agent Transport Simulation

Example: Time-dependent Toll

- Morning Traffic (08:00)

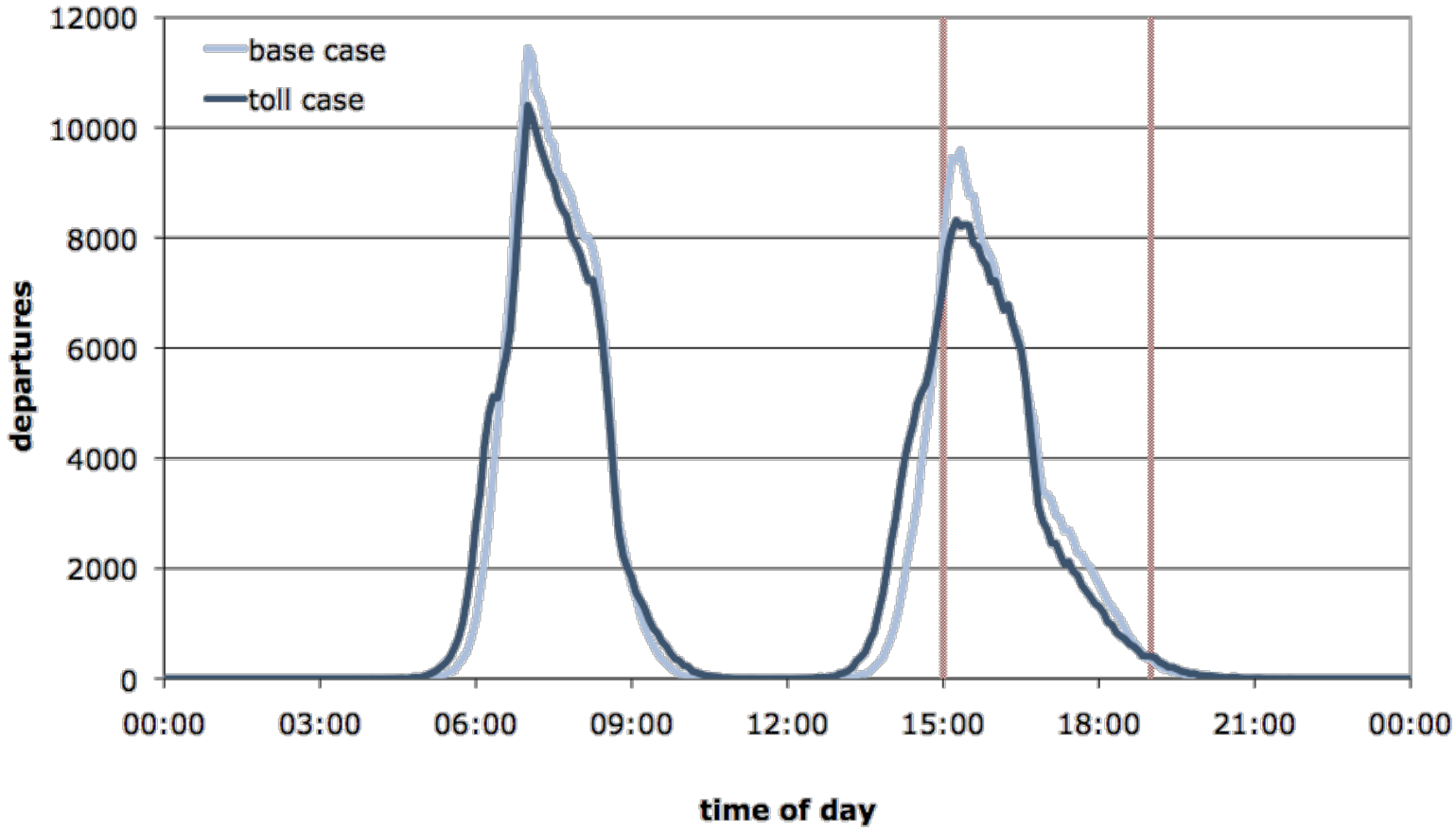
base case: big traffic jams in city

toll case: no traffic jams, even without active toll at that time!

MATSim
Multi-Agent Transport Simulation

Example: Time-dependent Toll

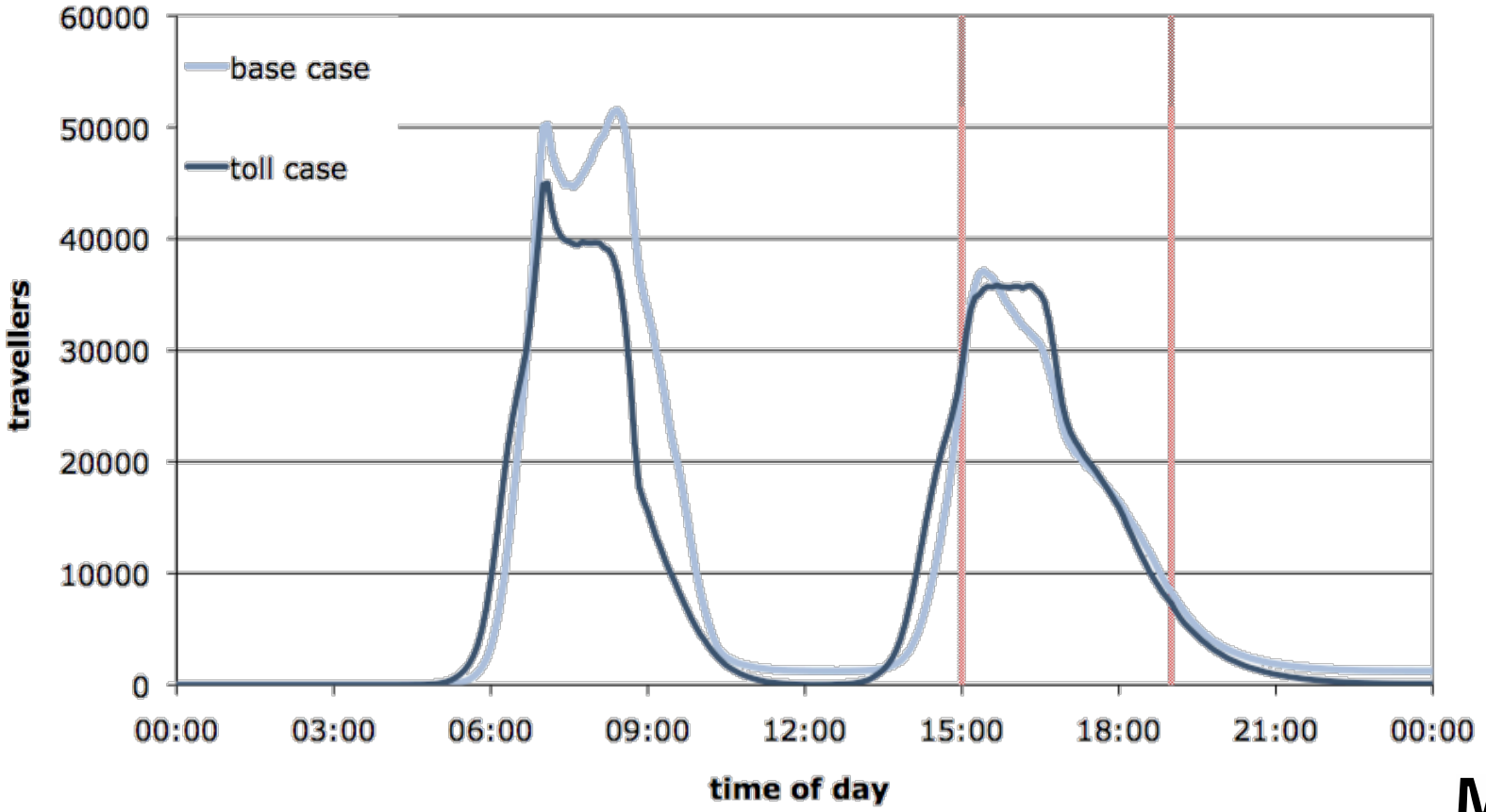
- Only commuters ("home-work-home") simulated
- Afternoon toll affects morning traffic pattern



MATSim
Multi-Agent Transport Simulation

Example: Time-dependent Toll

- Relatively small change in departure rates causes rather large change in number of vehicles in system



MATSim
Multi-Agent Transport Simulation

Agents' Reaction on a Toll

$$U_{total} = \sum_{i=1}^{n} U_{perf,i} + \sum_{i=1}^{n} U_{late,i} + \sum_{i=1}^{n} U_{travel,i} + U_{tolls\ paid}$$

- Reschedule activity durations to travel before/after toll (if time-dependent toll)
- Arriving late at activity (if time-dependent toll)

- But still forced to use a car and thus possibly paying toll

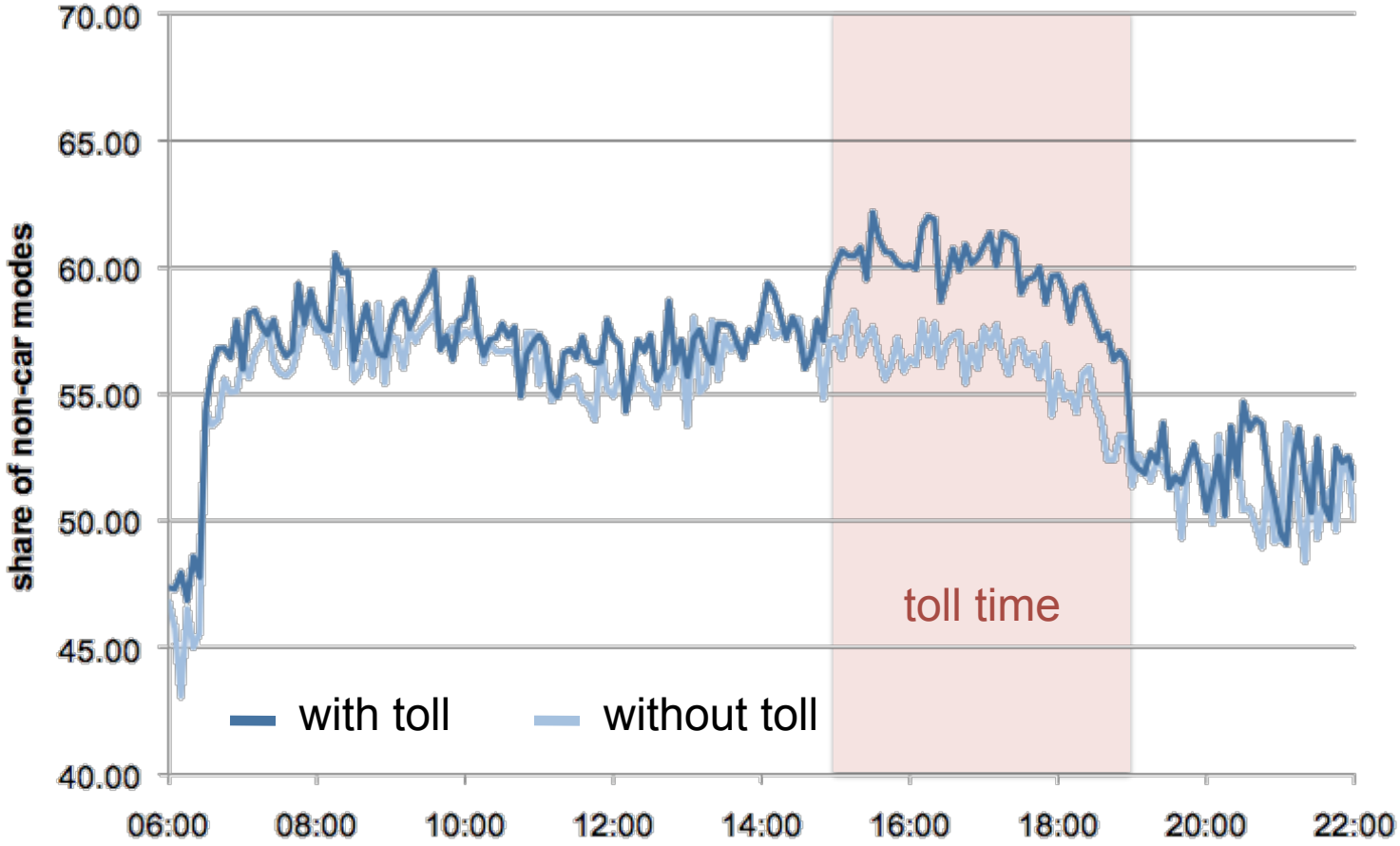
Adding Public Transit to MATSim

Adding Public Transit to MATSim

- Scoring: U_{travel} must take mode into account
  - Different VoT for public transit
  - (Disutilities for changing lines, waiting times, …)
- Replanning: must generate plans with different modes
  - Calculate / Estimate travel times for public transit
  - (calculate routes for public transit)
  - (randomly try out new transportation modes)
- Execution: must handle PT plans/routes
  - Teleport agents from one activity to next one
  - (simulate PT vehicles and agents walking)

Toll Case / Comparison

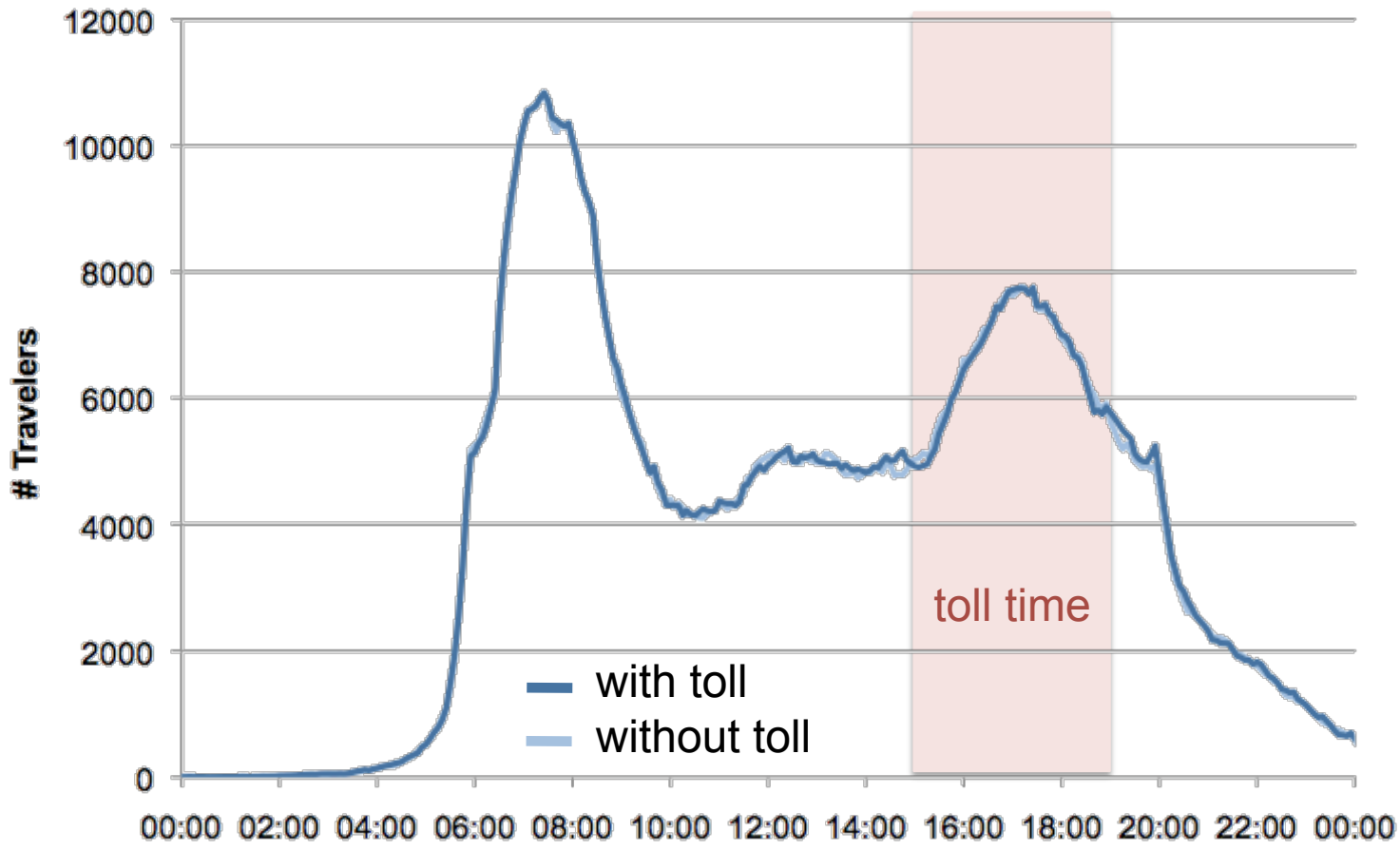
- Distance toll 50 ct/km from 15:00 to 19:00 in city of Zurich



MATSim
Multi-Agent Transport Simulation

Toll Case: Travel Volumes

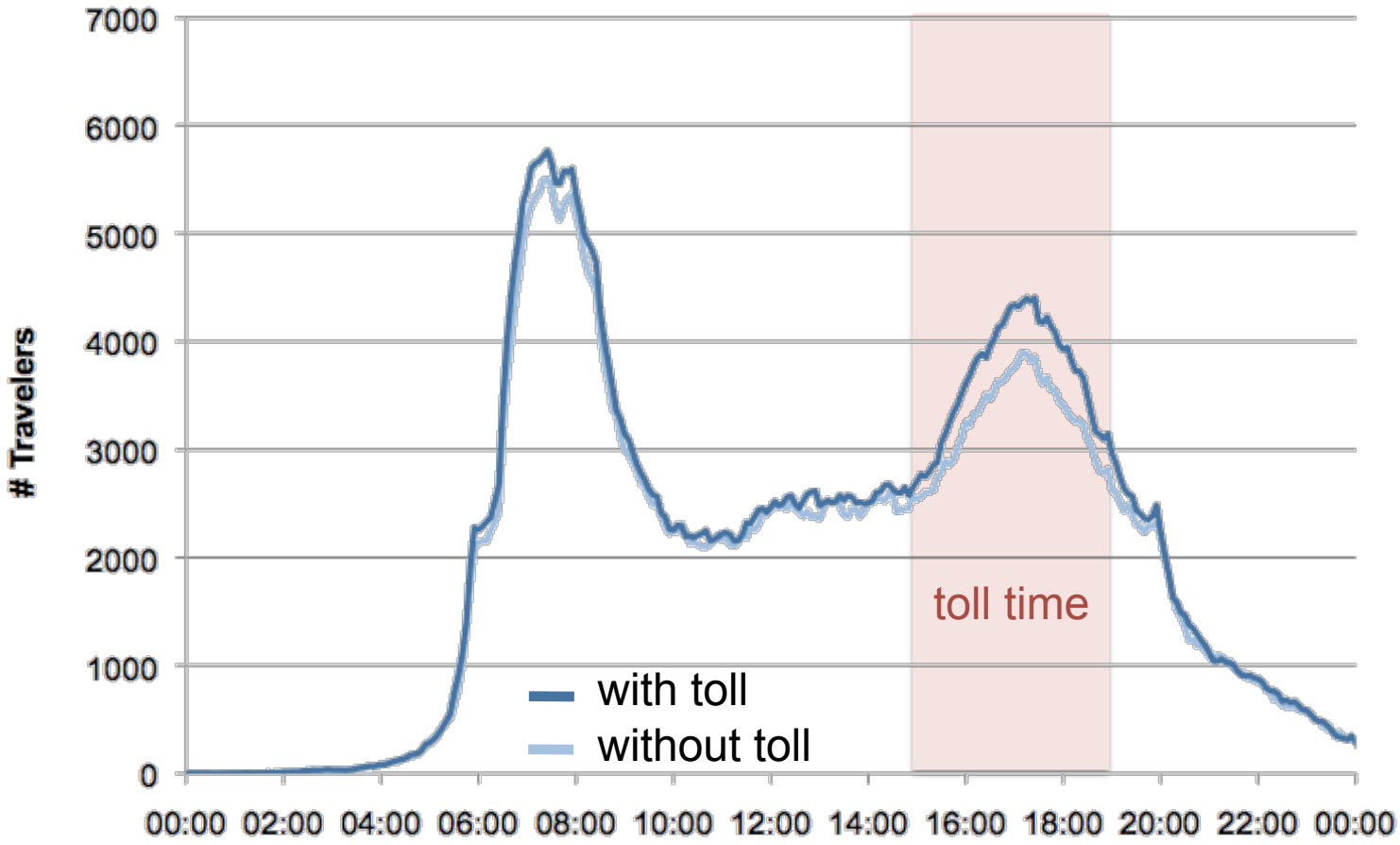
Nearly identical travel volumes between base case and toll case



MATSim
Multi-Agent Transport Simulation

Toll Case: Non-Car Travel Volumes

More non-car traffic during toll hours, and during morning peak



MATSim
Multi-Agent Transport Simulation

Future Work

- Improve scoring
  - Better utilility function for public transport / non-car modes
- Improve Replanning
  - Include time table information in router
  - Allow subtour-based mode choice
- Improve Transport Simulation
  - No longer teleportation, but real simulation of public transit and possibly other modes

- Verify results with real world data

Conclusion

- MATSim simulates full daily plans
- Non-car modes (and similar things) added as additional alternatives to agents' plans.
  Everything else functions as before.

- Changes of the utility landscape such as toll added to the agents' scoring function.
  Everything else functions as before.
- Consistent behavioral reaction to temporal aspects of policy measures.