Dynamic Policy Sensitive Model of Travel Demand

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May 2014

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understanding mobility

Coupling ABD Model of NY with MATSim

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Traffic Flow Simulation of New York

From the Four Step Process to the Modular MATSim Approach

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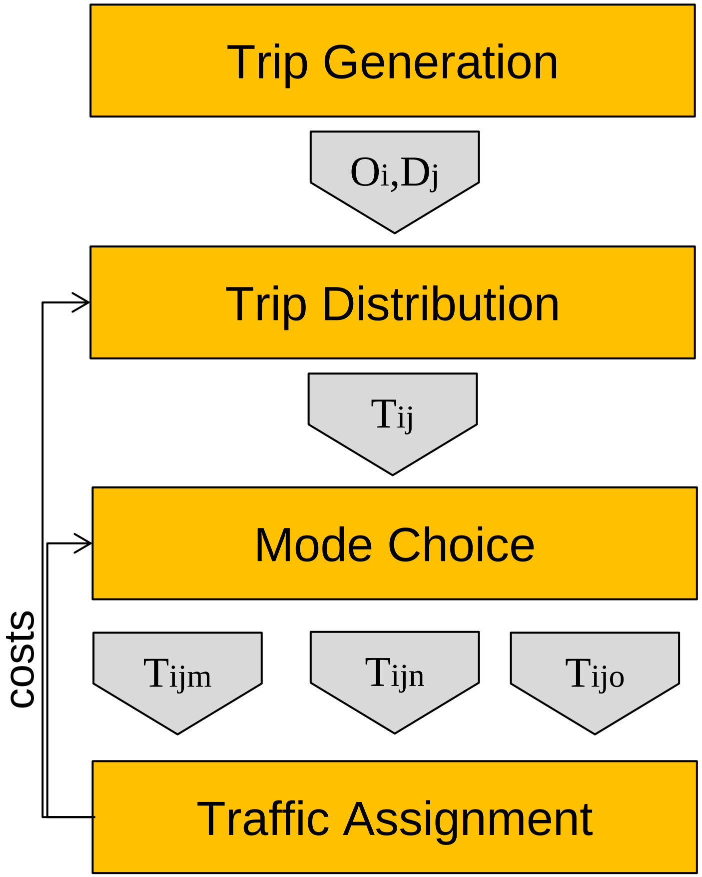
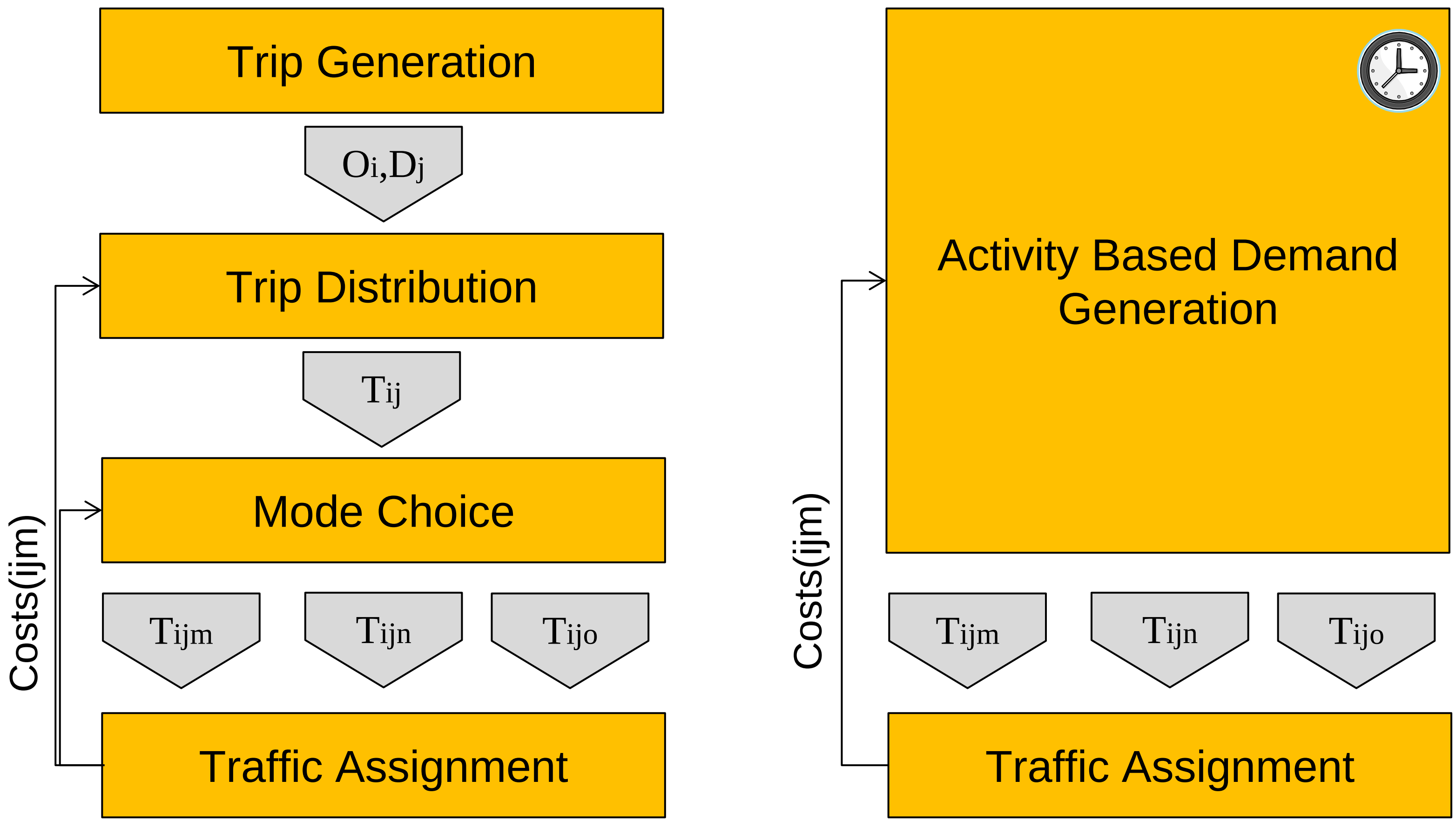
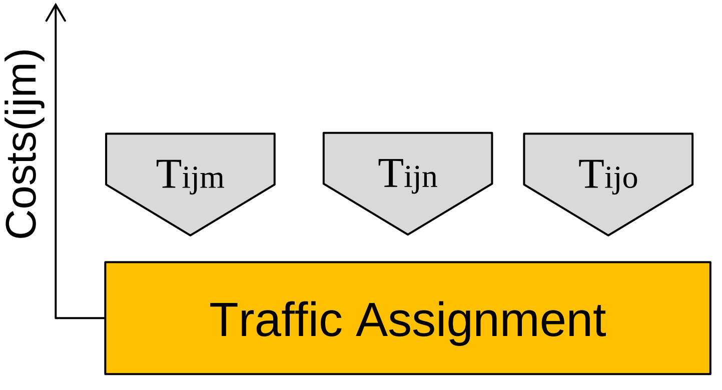
From the 4-Step-Process



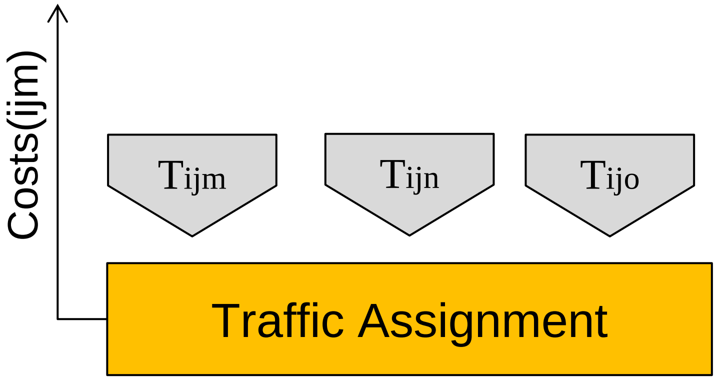
From the 4-Step-Process to ABDG

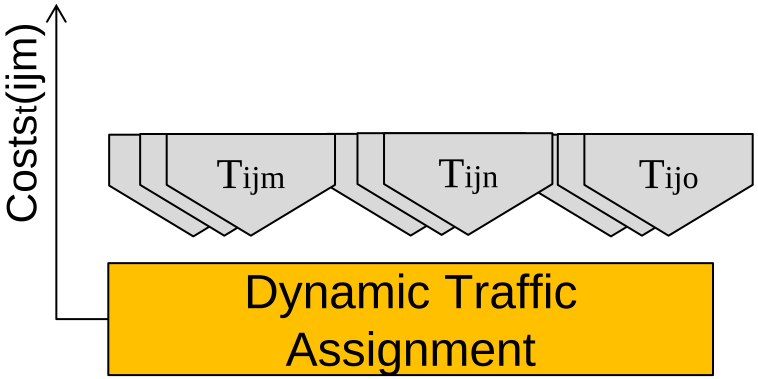


From the TA

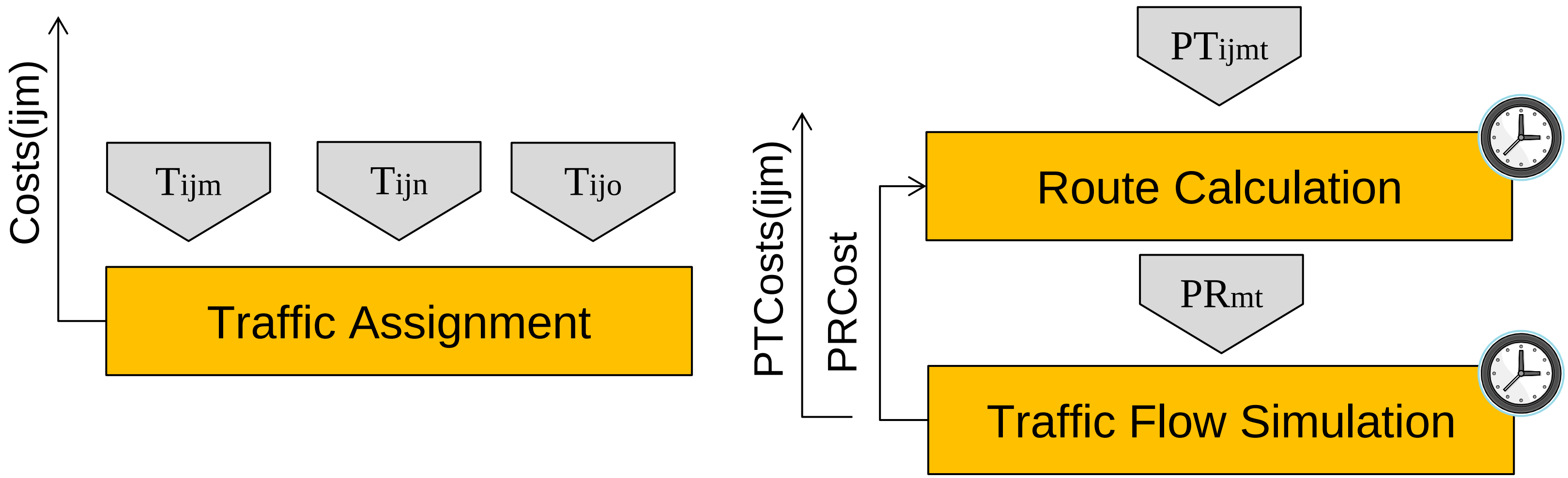


From the TA to the DTA





From the TA to the DTA to the Traffic Flow Simulation



From the TA to the DTA to the Traffic Flow Simulation

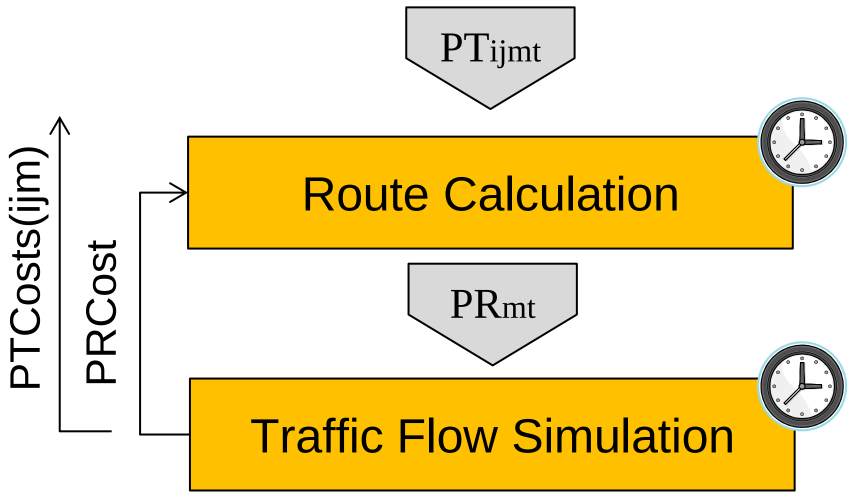
- Separate route calculation and simulation
- Iterate until the system relaxes

Features:

- Each single trip is routed separately and simulated synchronously
- Each single trip defines its specific departure time
- Each single trip belongs to a person

➔ Deliver a persons schedule ("plan") instead of single trips

➔ In other words: Deliver activity based demand

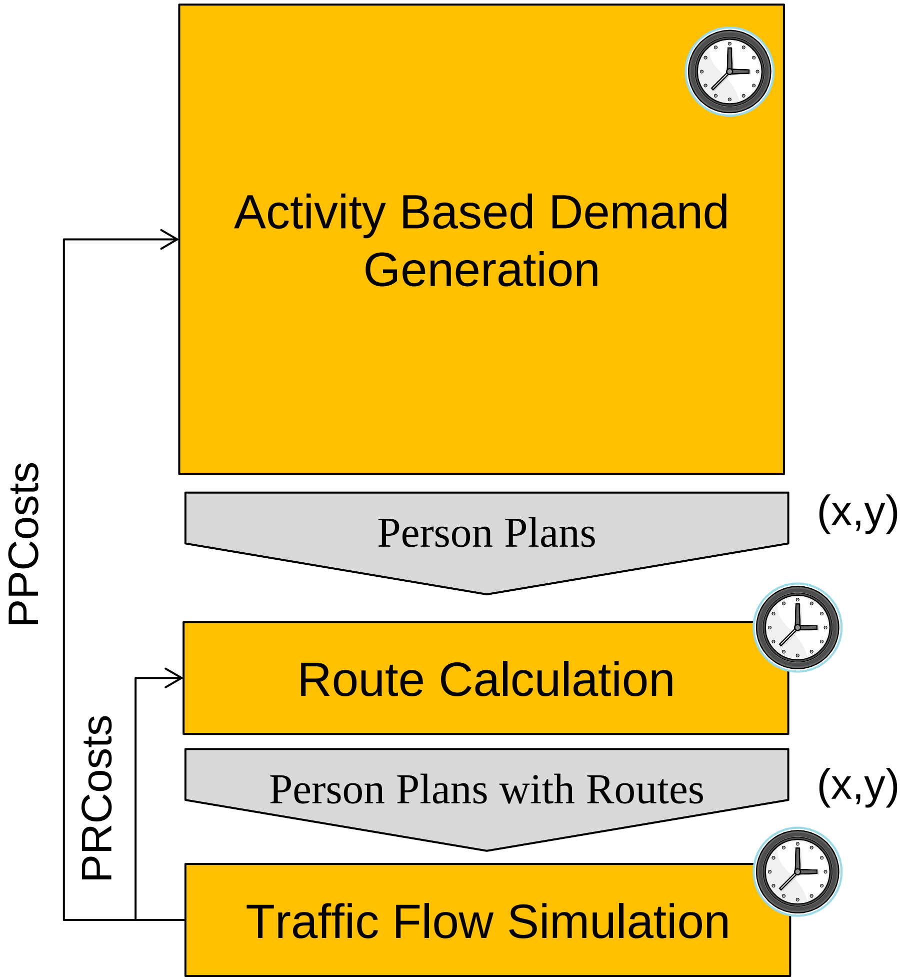


From the TA to the DTA to the Traffic Flow Simulation

More Features:

- Trip chains instead of trips
- Activity Locations can be assigned to a single Coordinate (no performance loss in computation)
- Activities and their durations can be modeled explicitly
- No matrices, no connectors
- Detailed, differentiated and personalized cost elements for the ABDG

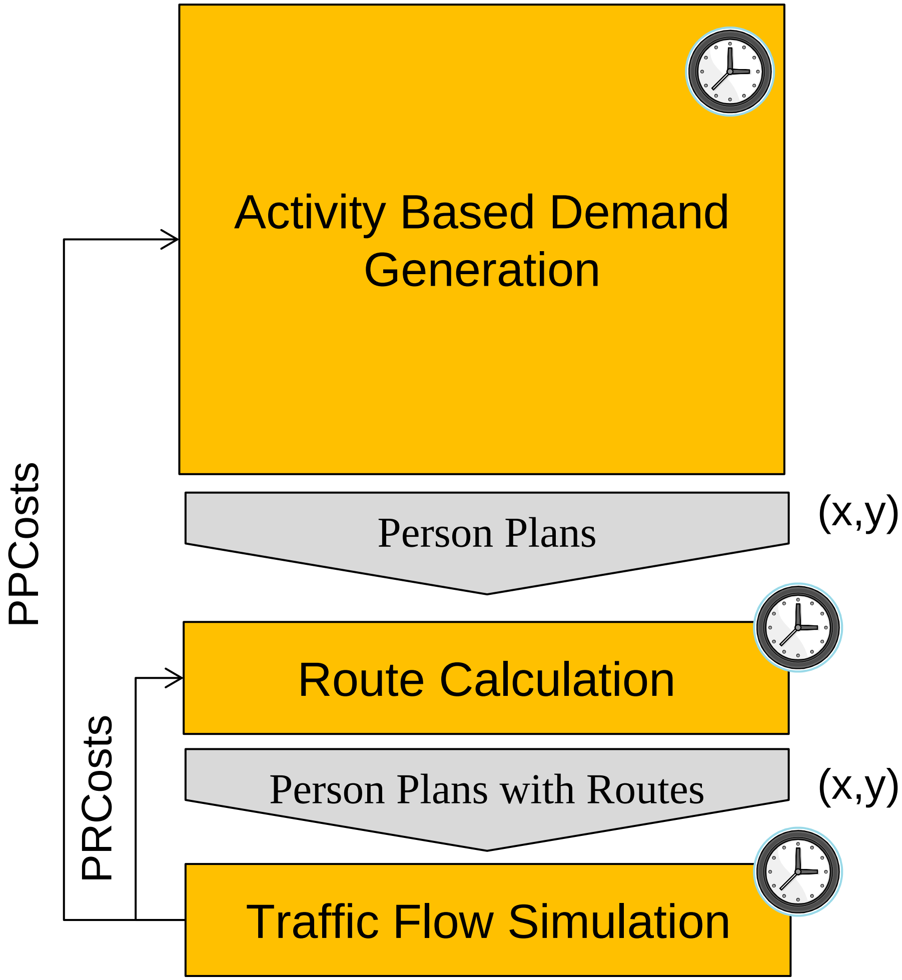
➔ The persons plans are the "natural" interface to the ABDG



From the TA to the DTA to the Traffic Flow Simulation

Even More Features:

- The model is (per definition) fully dynamic
- The model is fully schedule based for public transit
- The model is multimodal and fully integrated (i.e. busses can get stuck in congestion)
- Capacity constraints for all modes
- Accessibility and reachability can be modeled in high spatial and temporal resolution (i.e. important for car sharing)
- …



Implications

No zones, no connectors

➔ Supply can be modeled completely independent from the land use, population and demand (and vice versa).

Microscopic supply side modeling

➔ The network resolution defines the level of detail

➔ Transit: stop POINTS only

- ➔ Busses, trams, etc. stop exactly where they stop in reality
- ➔ Aggregated statistics and key values accessible on various level of detail (transit stops, transit stop regions, etc…)
- ➔ Transit line switch connections based on it geographic location. No line switch relations necessary

Transport model of a part of the region

➔ Every arbitrary part of the region is modeled completely

Performance Issues…?

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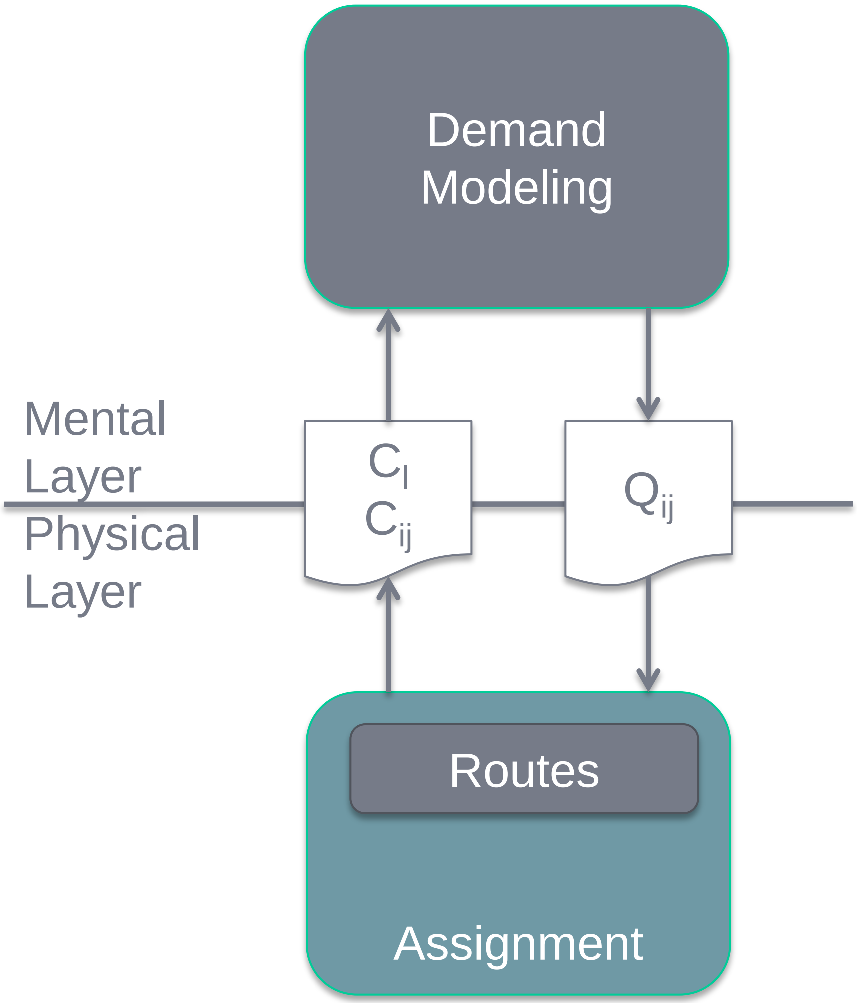
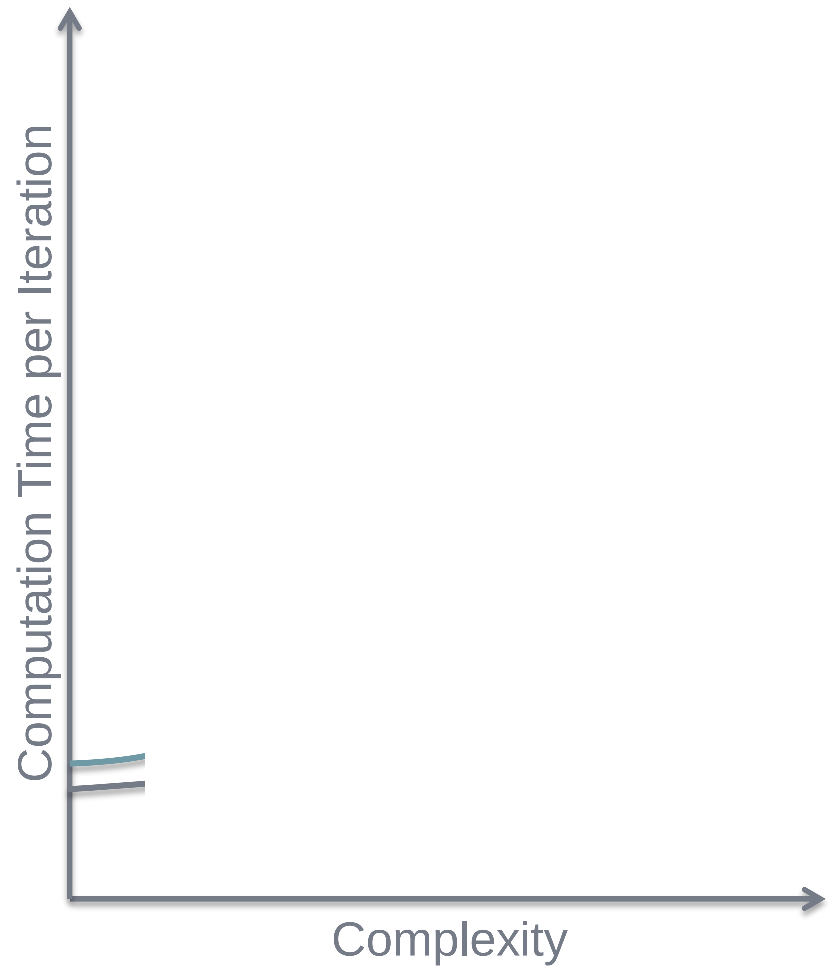
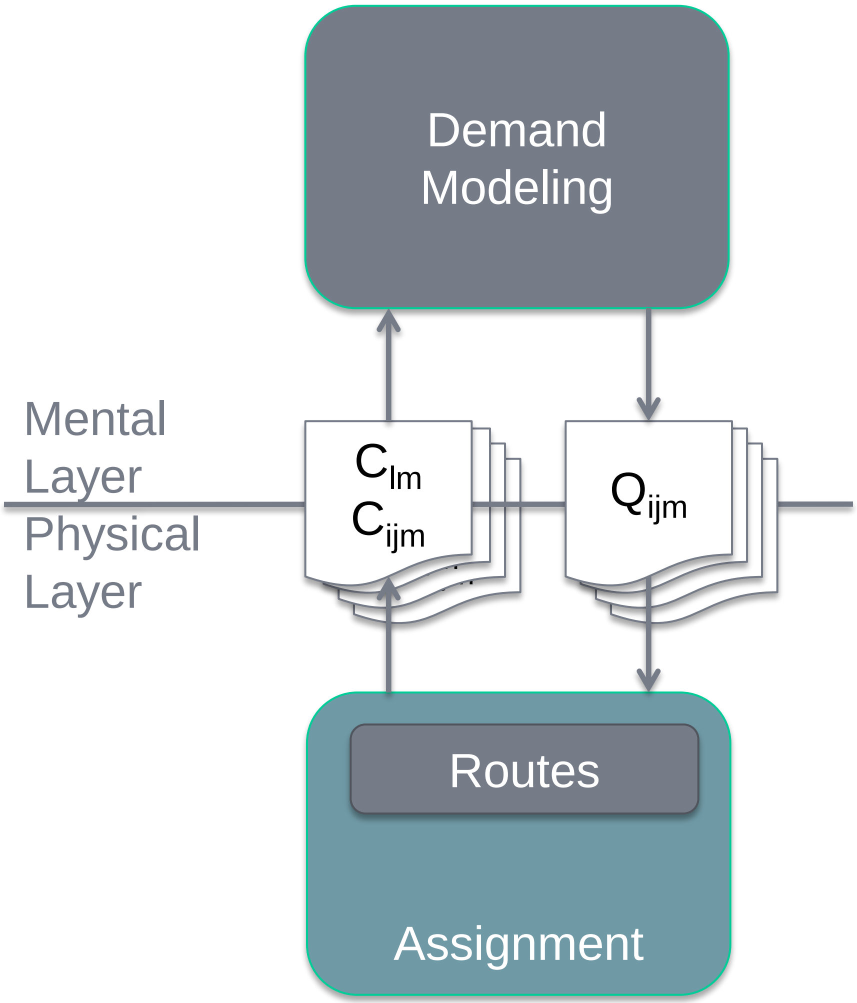
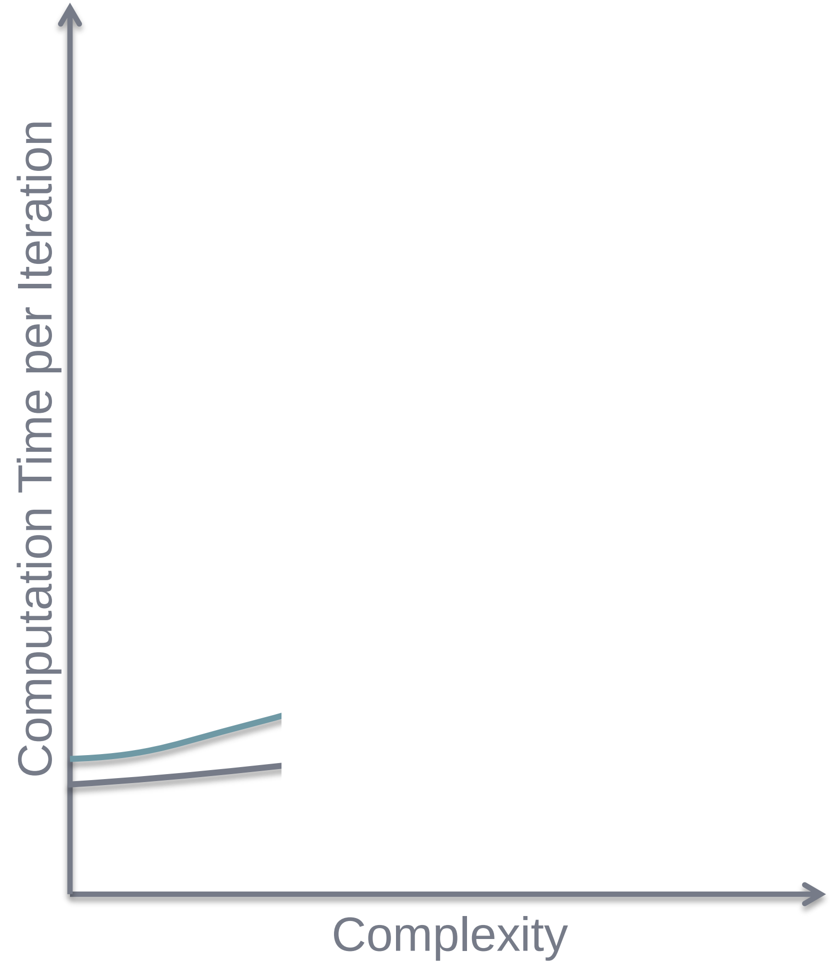
Demand and Assignment:
1 Mode, 1 Group, Static



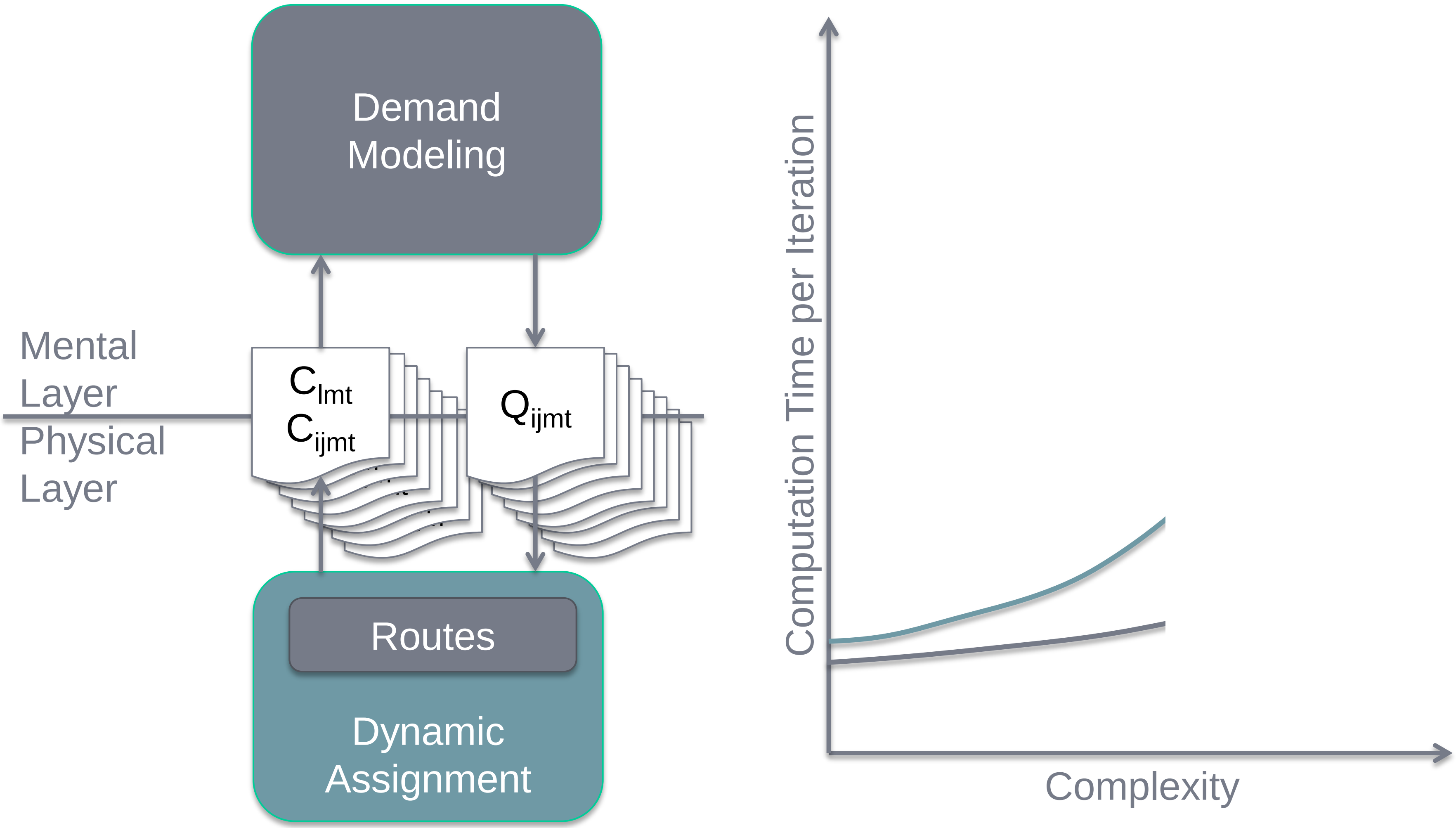


Demand and Assignment :
4 Modes, 1 Group, Static

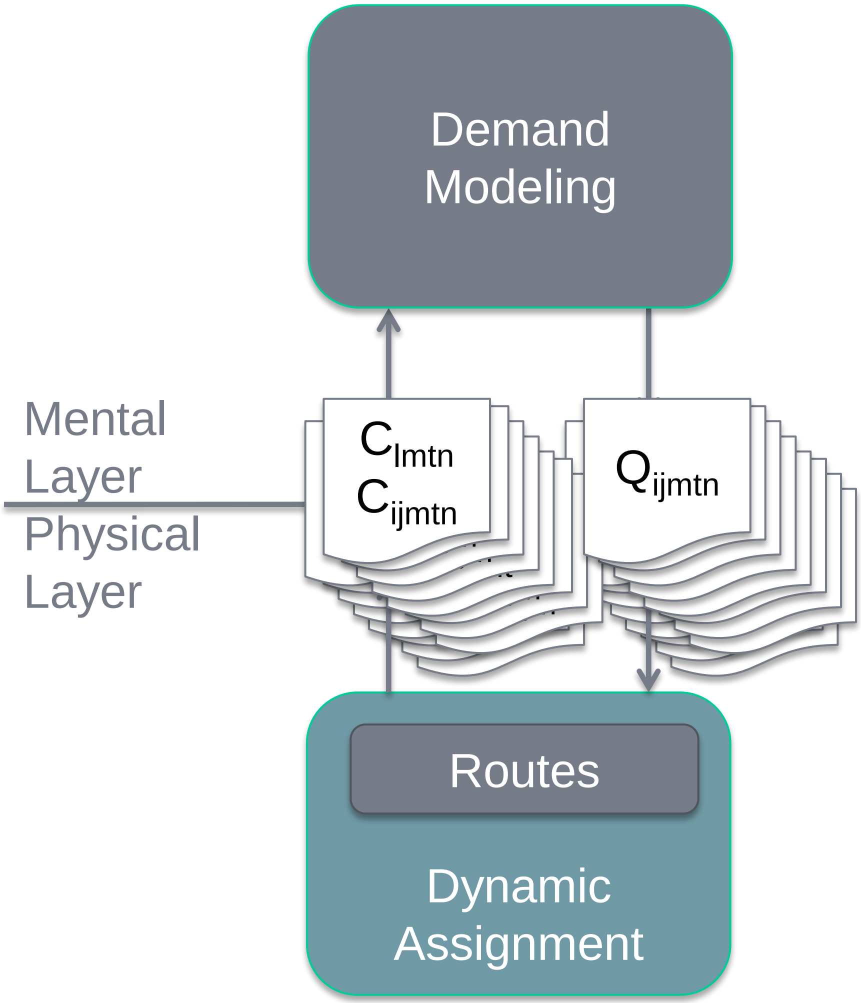


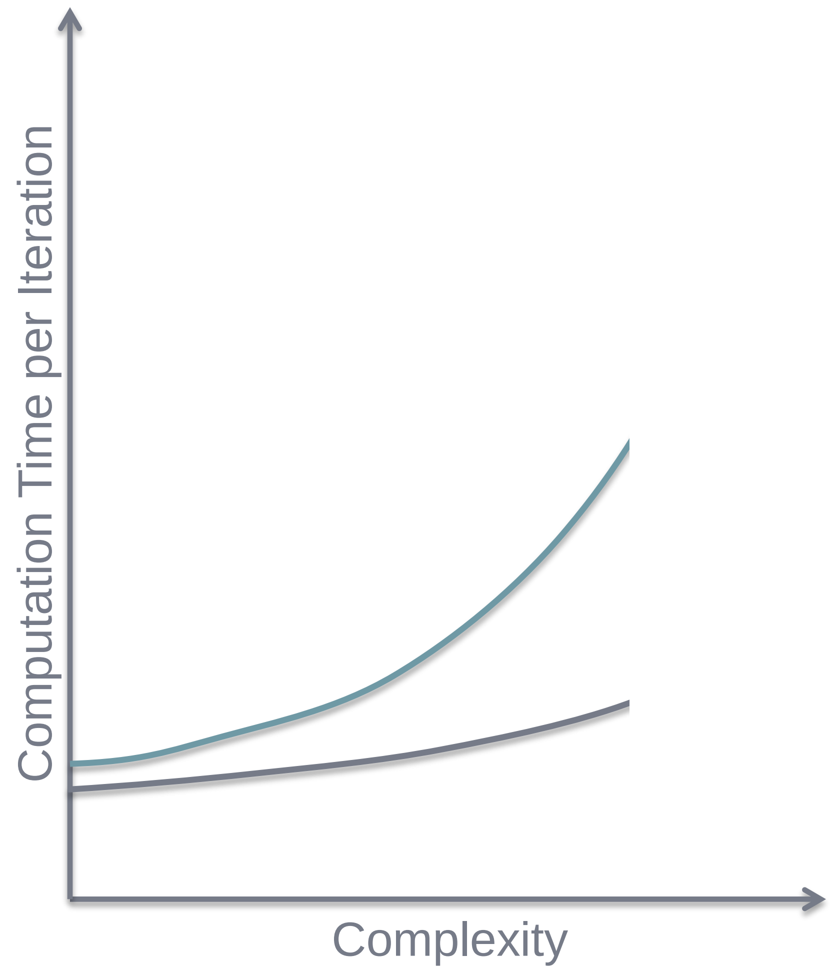


Demand and Assignment :
4 Modes, 1 Group, dynamic



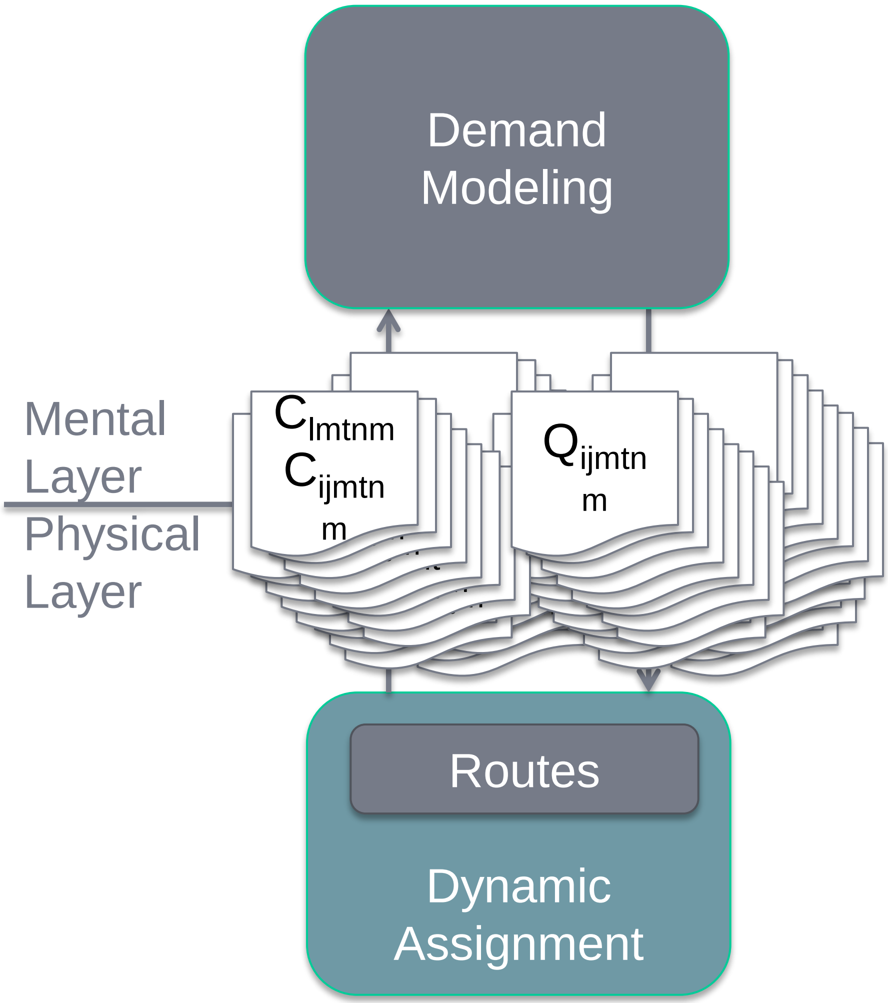
Demand and Assignment :
4 modes, *n* OD-Groups, dynamic

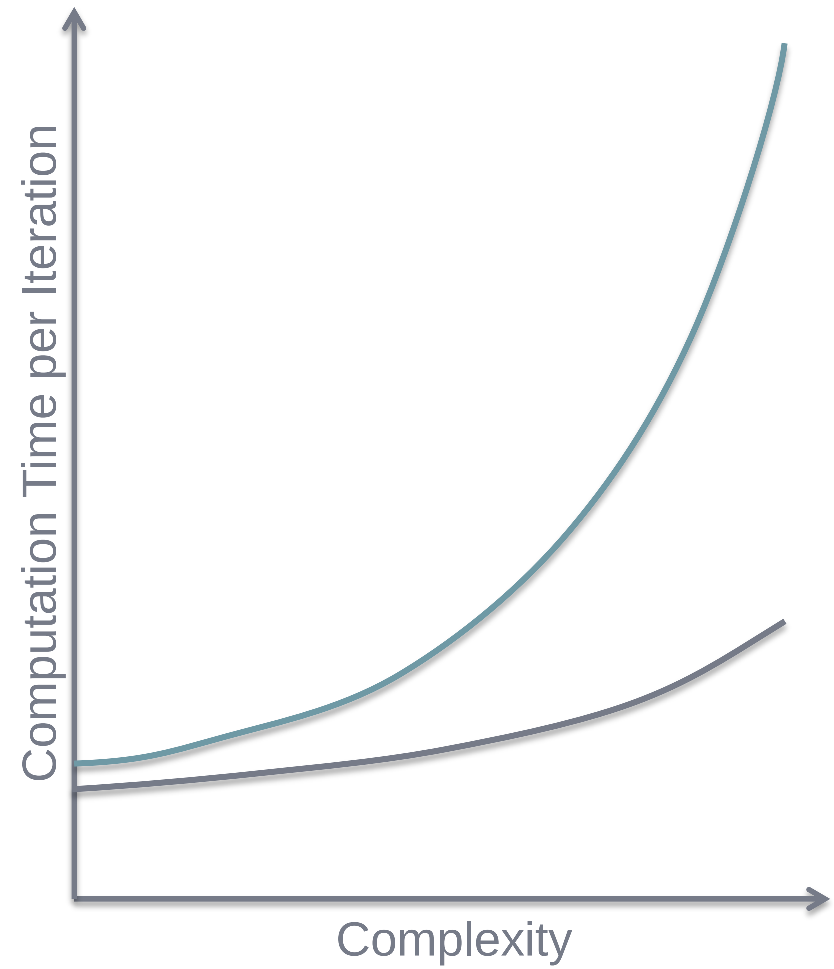




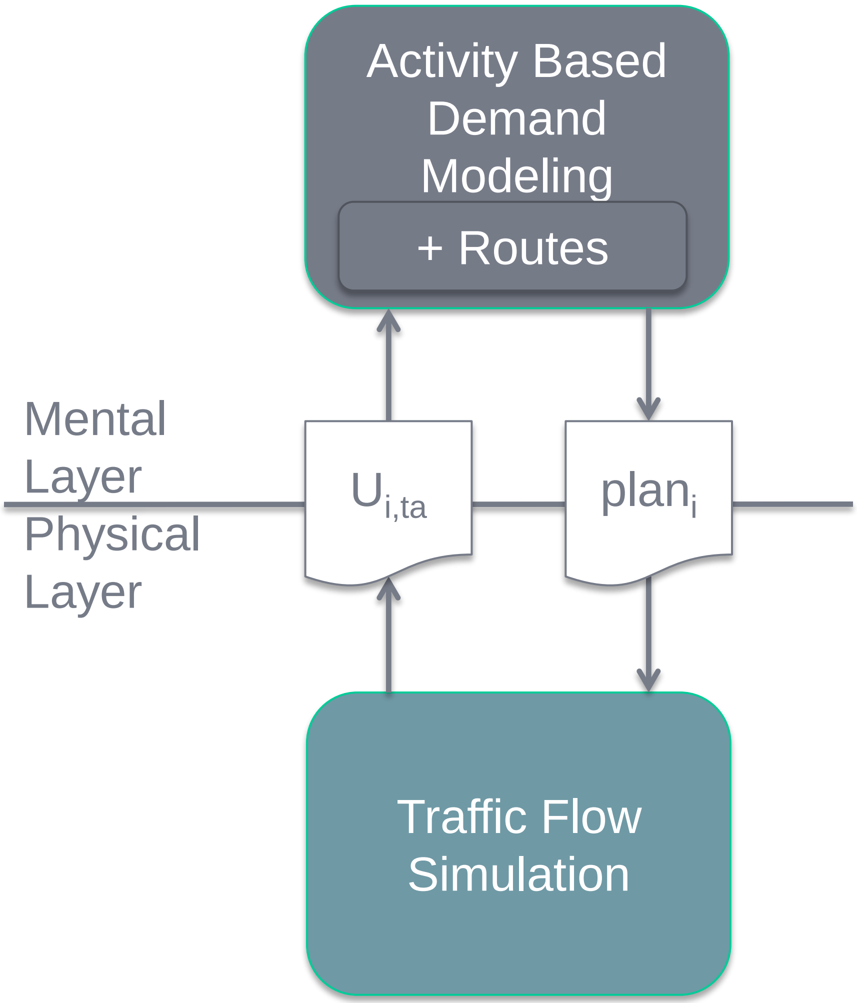
Demand and Assignment :

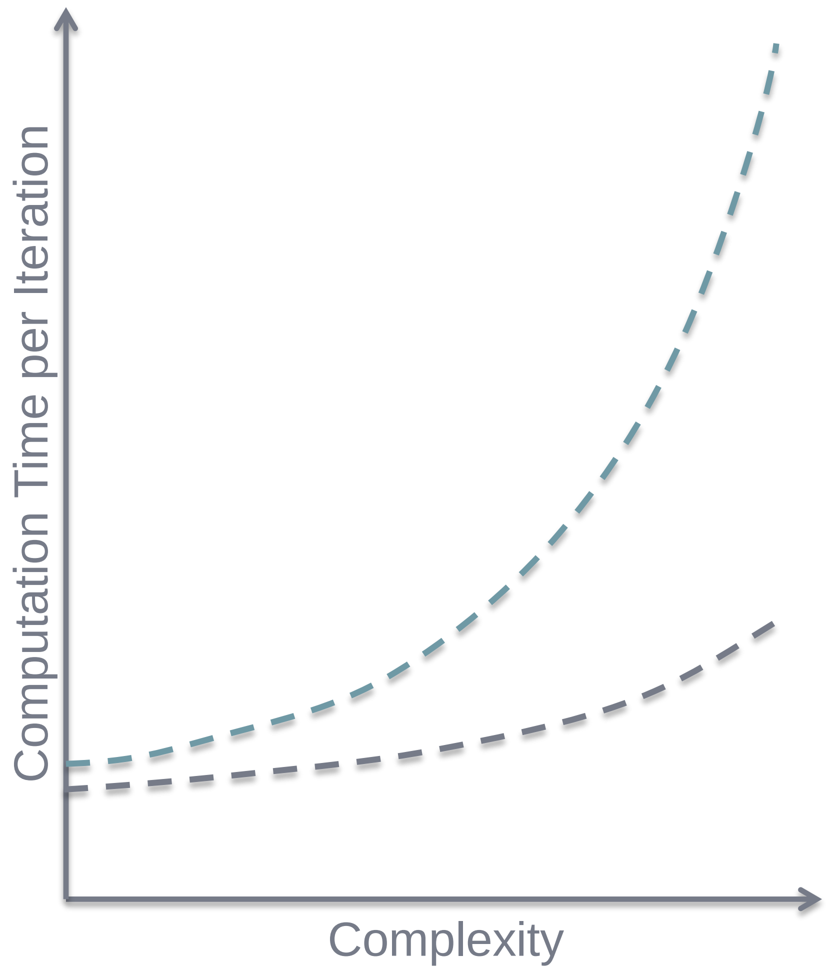
4 modes, *n* OD-Groups, m homogeneous Groups, dynamic



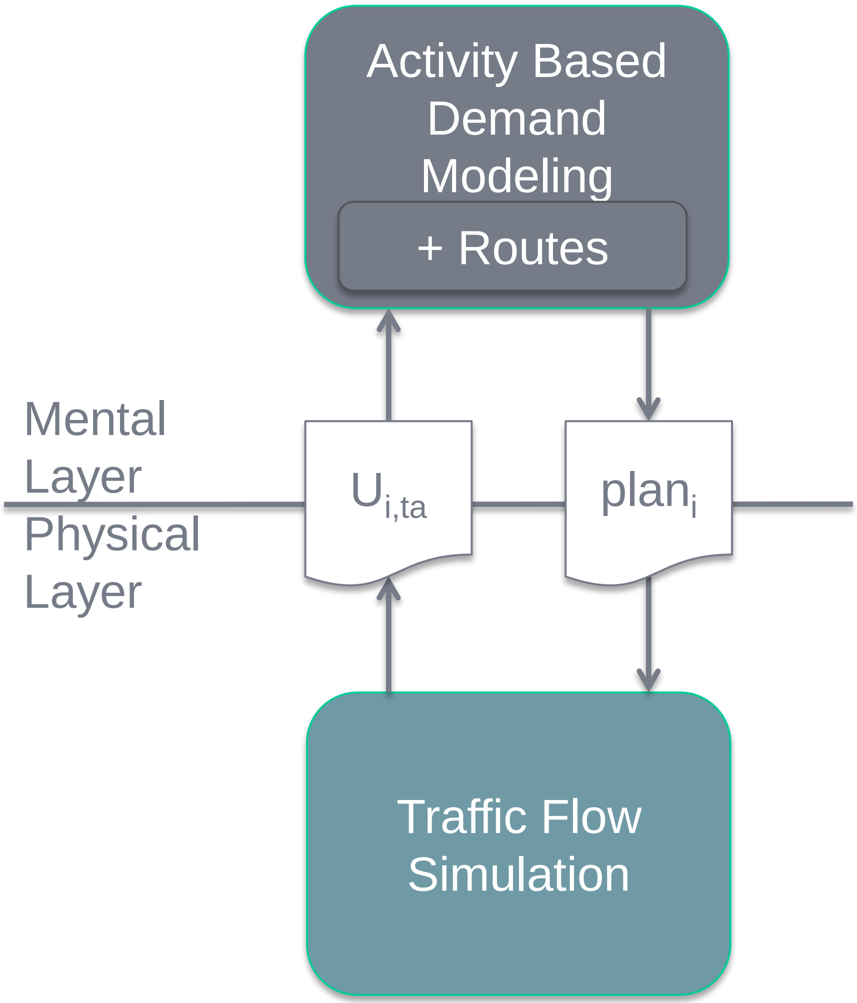


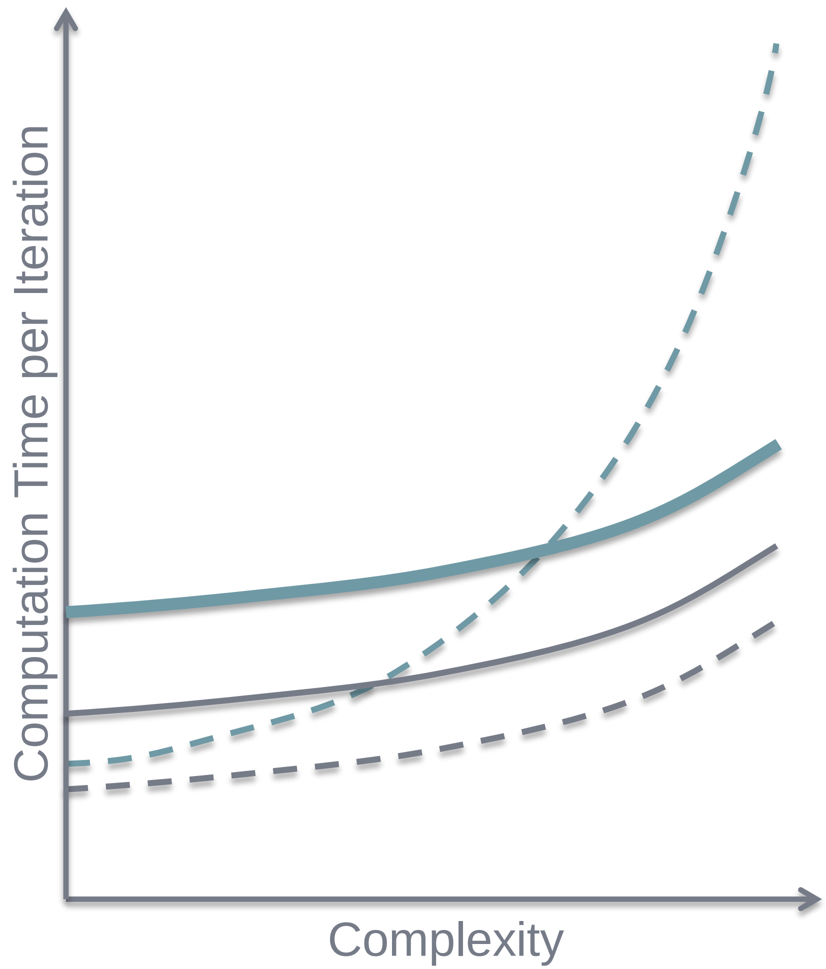
ABDG & Simulation





ABDG & Simulation





MATSim Demand Relaxation Process: IT’S MODULAR

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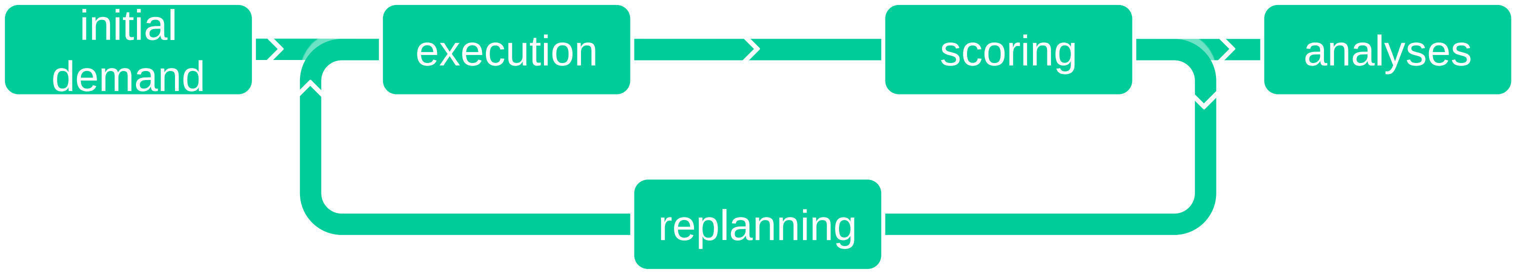
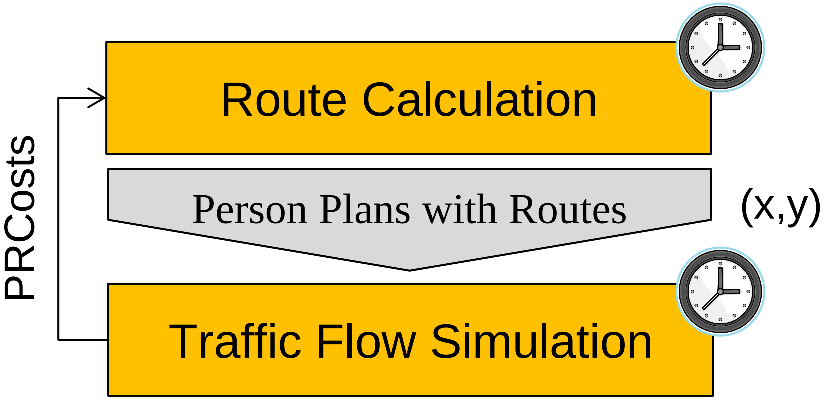
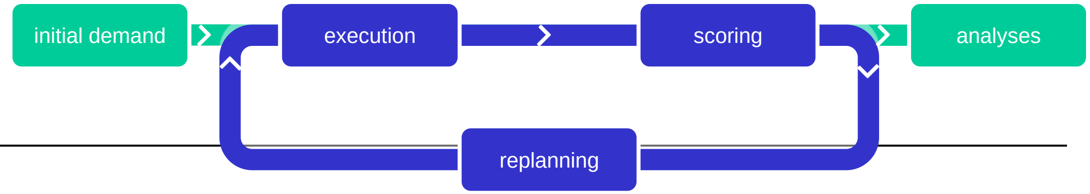
Calculation Cycle



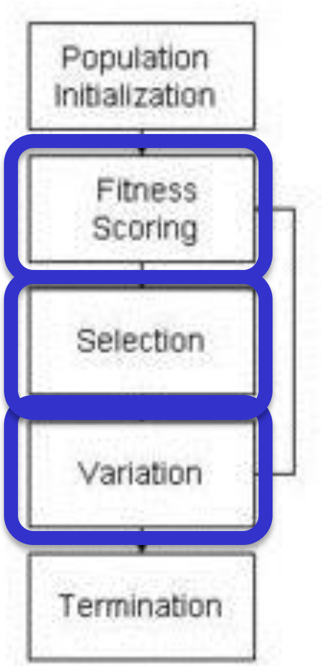




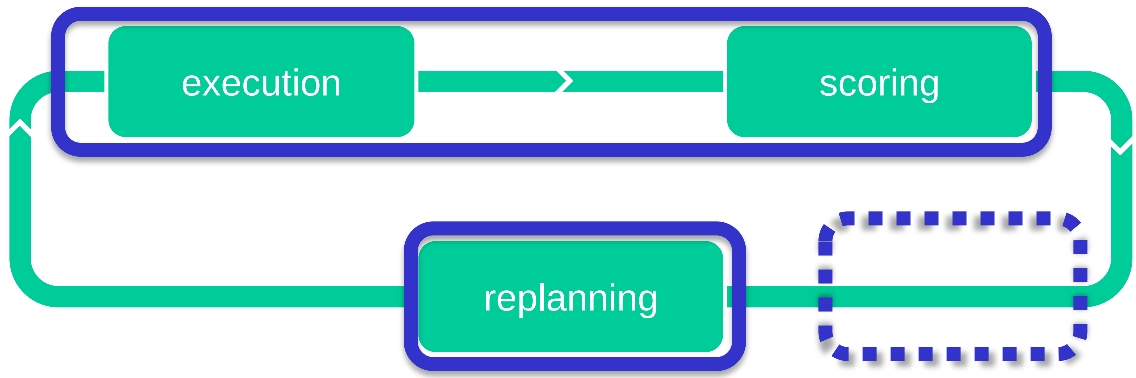
Optimization

Evolutionary Algorithm

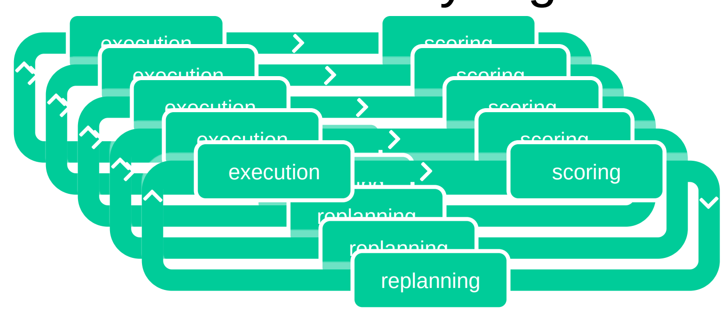
“Population of individuals”

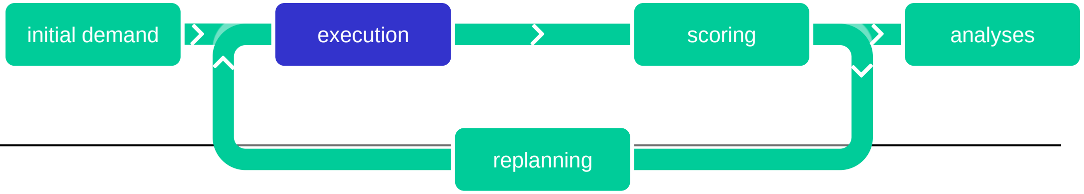


“Population of Plans”



Co-Evolutionary Algorithm





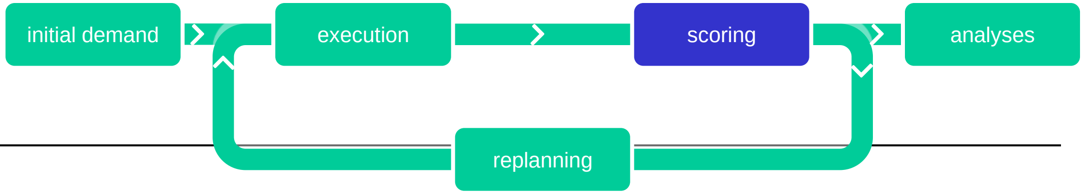
Optimization

Execution:

- Simultaneous execution of all persons with their selected plan
- Implementation: Queue model

Task:

- Traffic flow calculation
- Basis for calculation of the score of the plans



Optimization

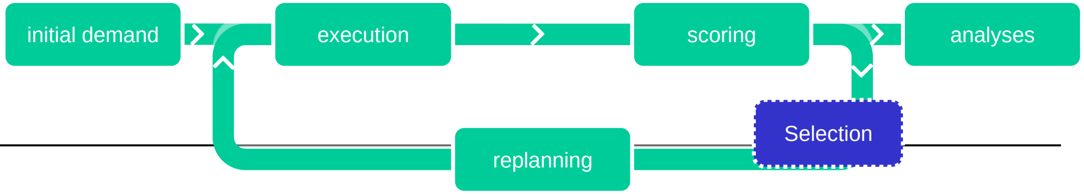
Scoring:

- Calculation of the “fitness” (Utility, Score, generalized (negative) costs)
- Implementation: Charypar und Nagel (2006) and many different extensions of that

Task:

- Scoring of an executed plan
- Basis for the plan’s likelihood to “survive”

Optimization

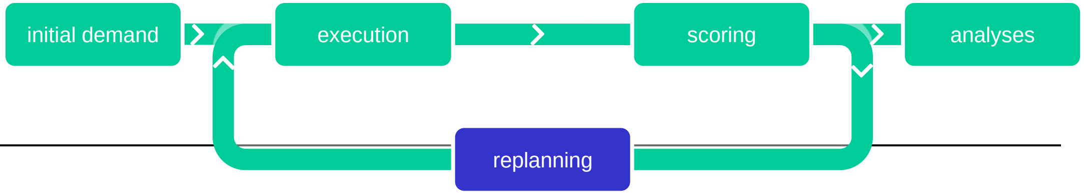


Selection:

- Defines how plans are generated, selected or deleted

Task:

- Selection process of the evolutionary algorithm



Optimization

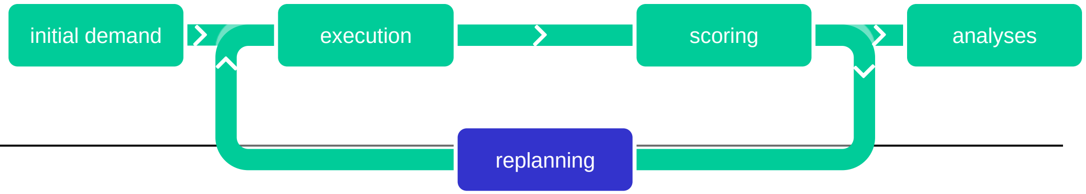
Replanning:

- The way how plans are mutated/changed/adapted (for creation of a ne plan)

Task:

- Searching in the search space

➔ The replanning modules define the search space!



Optimization

Routes

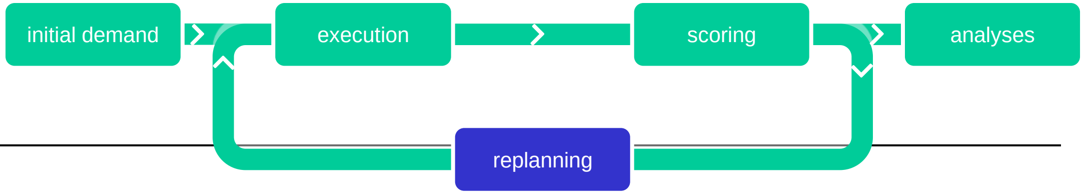
- Typically variations of the dynamic Dijkstra Routing algorithm
  ➔ “Best respond module”

Times

- “Time Allocator Mutator”: random variation of departure times and durations of activities
  ➔ “Random mutation module”

Modes

- “Mode Mutator”: Random mode choice on trip, sub-tour or Plan basis ➔ “Random mutation module”



Optimization

Locations

- Secondary Location Choice Module:
  - Random location choice from a given set of possibilities
    ➔ “Random mutation module”
  - selection via Space-Time prism
    ➔ ~ “Best respond module”

Summary

- Replanning: Searching in the search space
- Simulation & Utility Function: Calculation of the success of a plan
- Utility Function: It describes the mobility behavior
- Plan pruning: „Survival of the fittest“, resp. “none survival of the none fittest”
- The final plan set per person: The result of the (plan) choice set generation per person

IT'S MODULAR

Possibilities:

- Simulation: Replace the Queue Model by your own one (e.g. a CA Model)
- Utility Function: Adapt/Extend/Replace the utility function by your own needs

For the New York show case:

- Using the activity based demand generation process of NY (chains, activity types, modes and times per person group and home location)
- Replanning: Only MATSim route replanning (switching off the other replanning modules)

New York Modeling Process

Senozon @ PB

Coupling PB ABDG with MATSim

ABD is

- Individual chain based
- Zonal based
- Time distribution based

Conversion Process

- Distribute in space (according to land use and buildings)
- Distribute in time (according to time distribution of ABD)

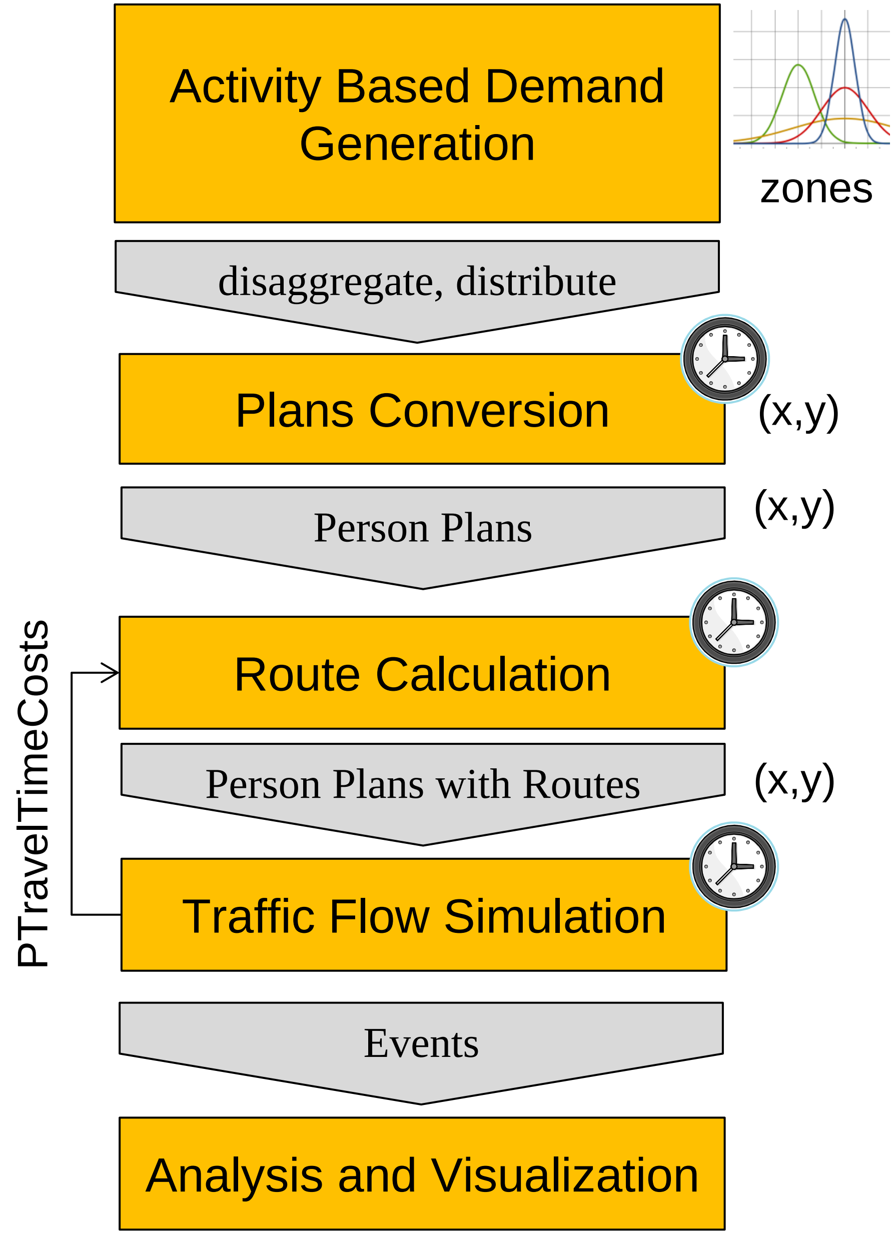
➔ MATSim initial Plans

Route assignment

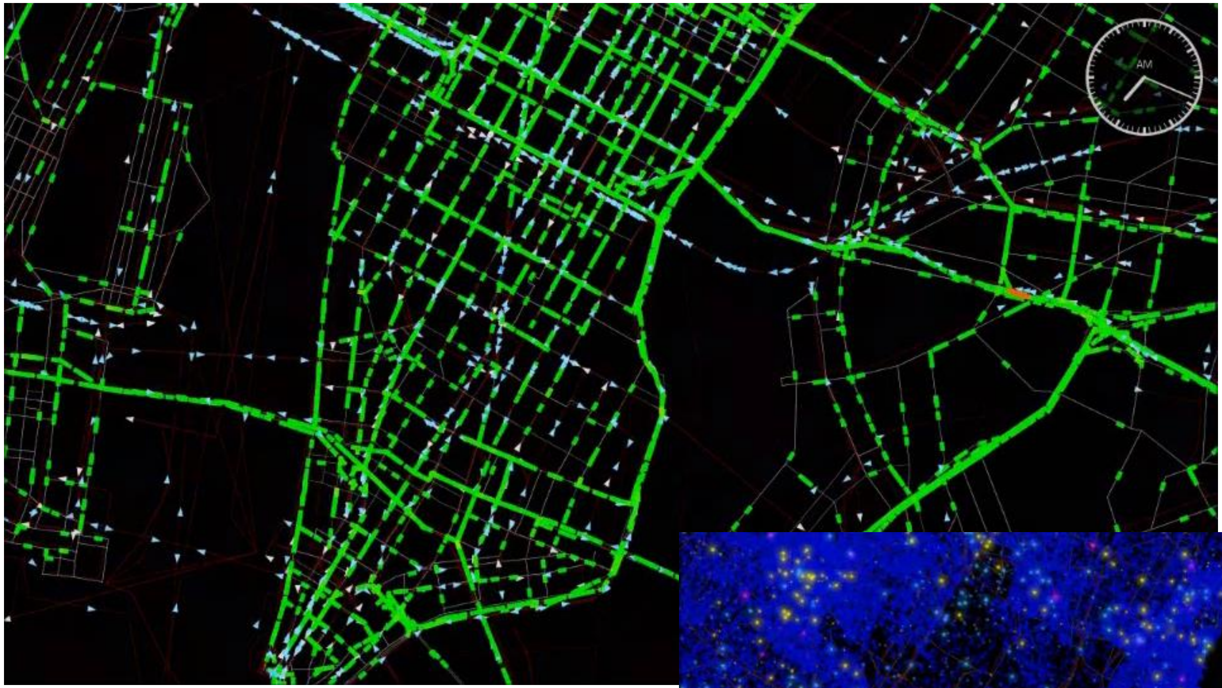
- Based on travel time costs

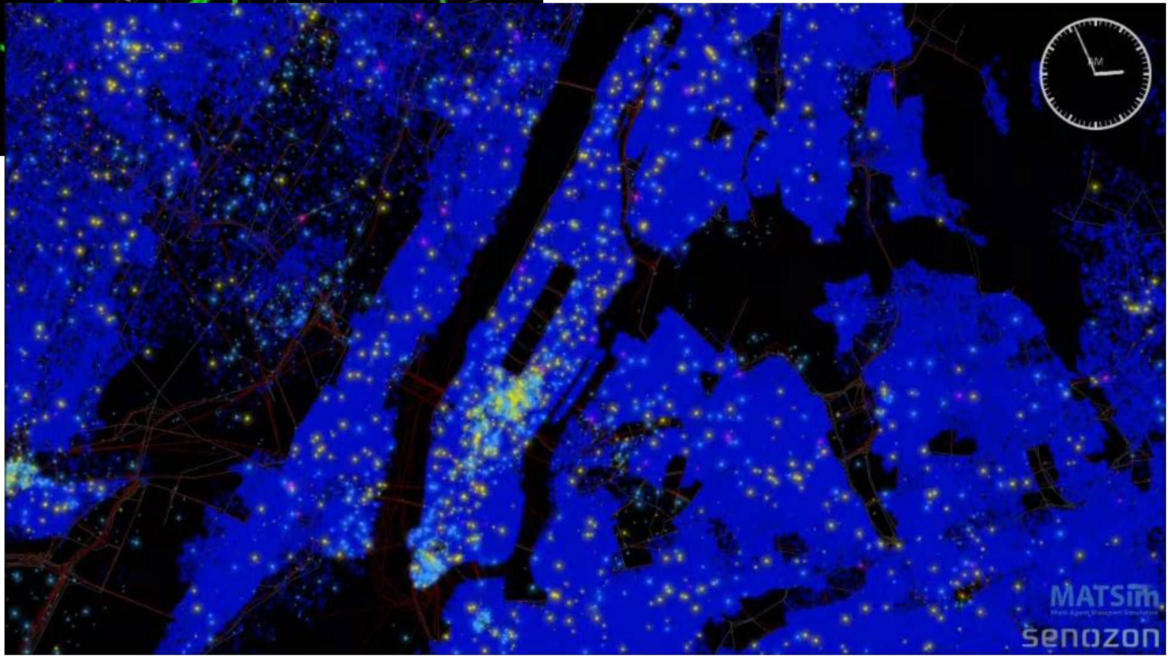
Analysis and Visualization

- Aggregate in time, space, modes and/or person groups (and much more…)



Example Analysis: Visualization

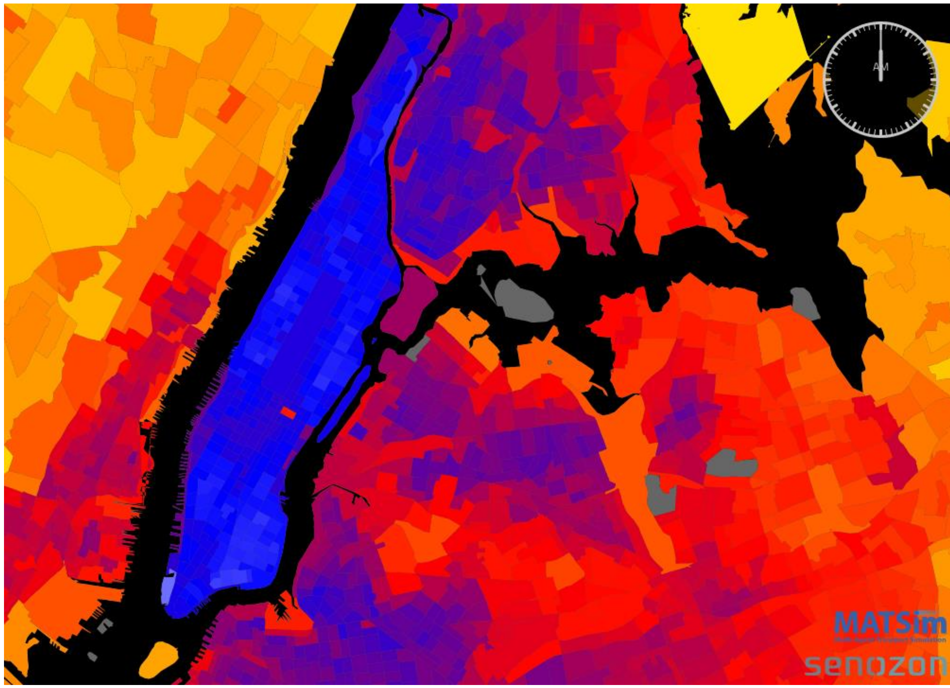




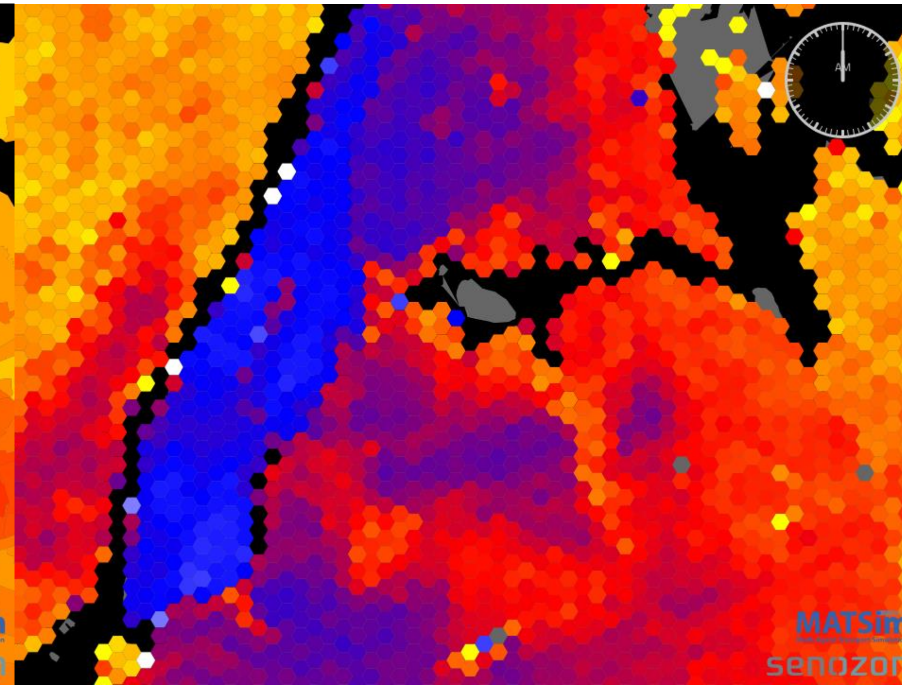
low med. high

Example Analysis: Mode Shares

Car mode shares on different spatial aggregation level



Based on TAZ



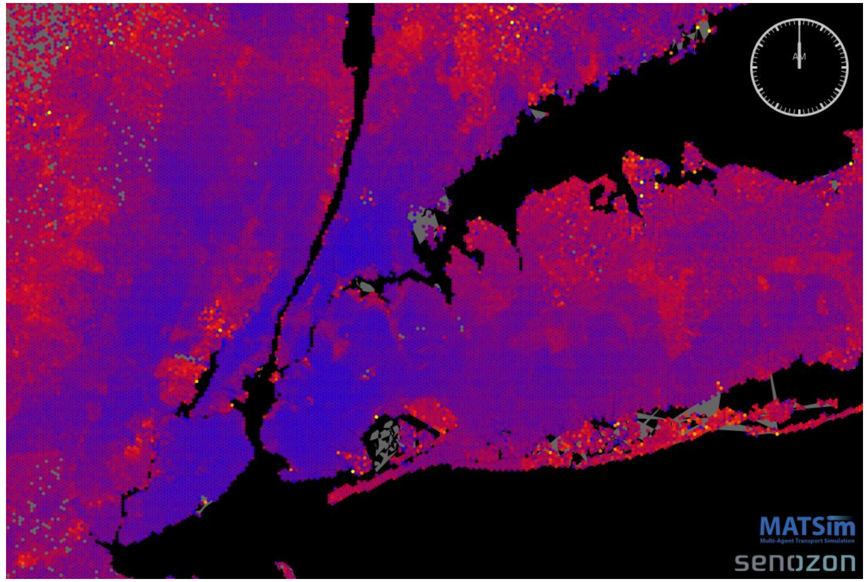
Based on hexagons

➔ The aggregation level can be arbitrary

Example Analysis: Trip Statistics

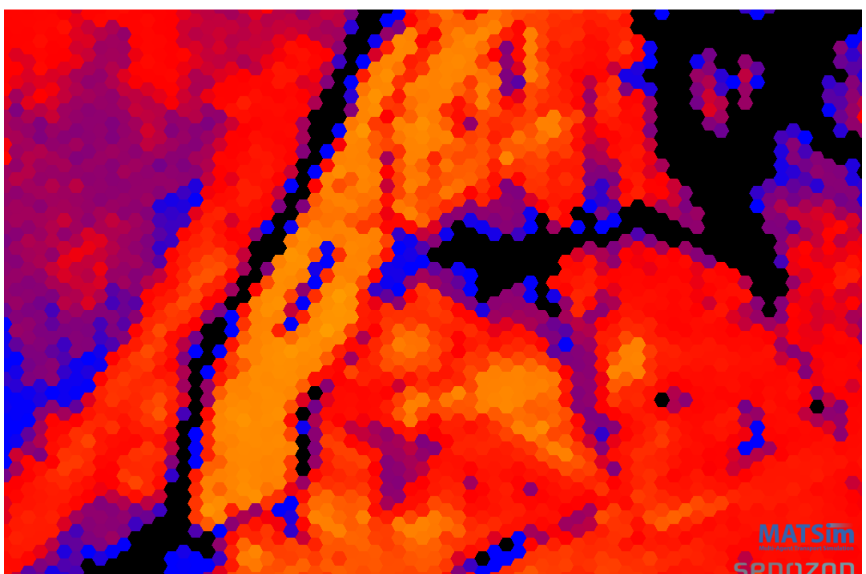
low med. high

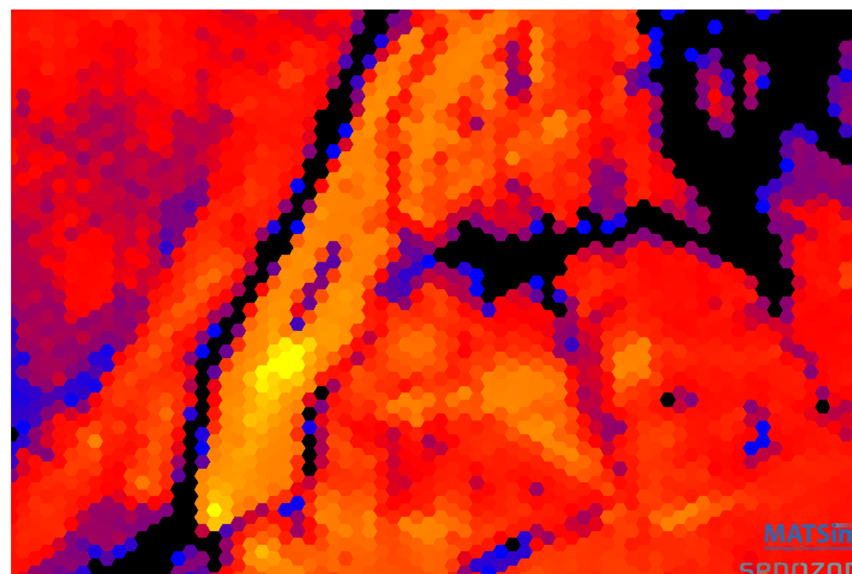
Average trip distance per hexagon



#trips before 10am

#trips after 3pm





New York Policy Study

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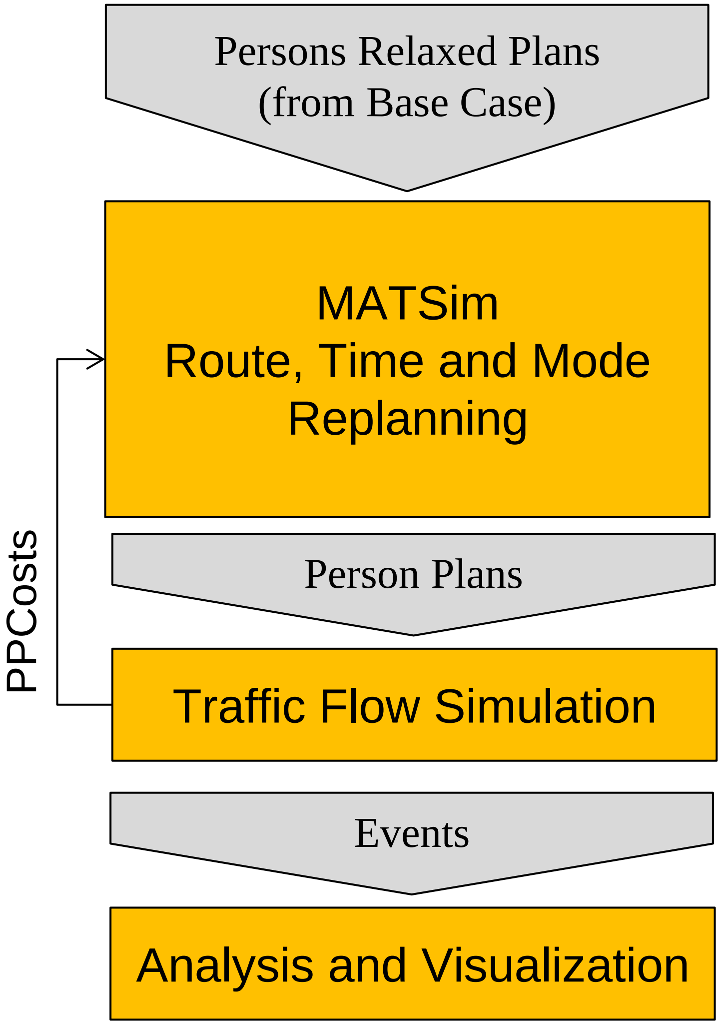
What if…

Mobility is completely free of costs (no car costs, no public transit costs, no fuel cost, etc.) and there is unlimited parking space (no constraints, no costs)

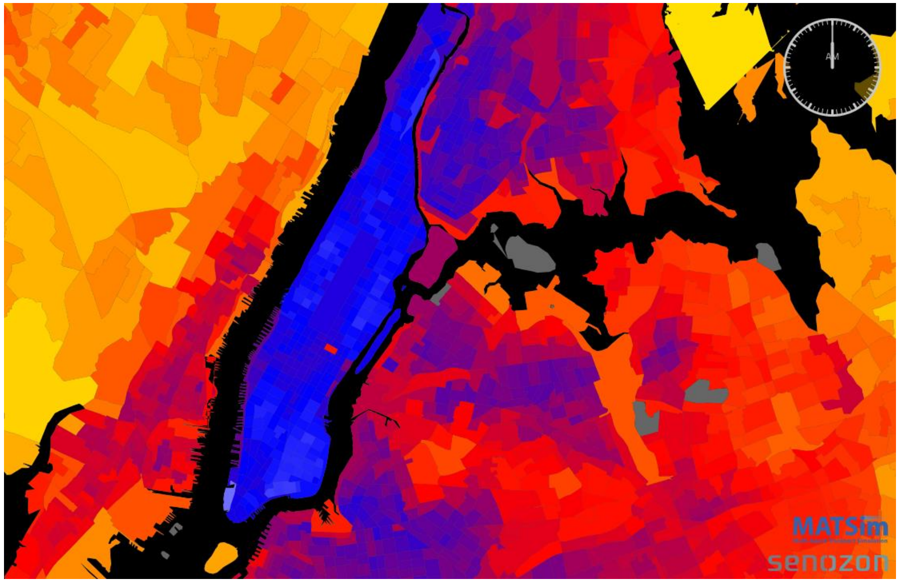


low med. high

Comparisons

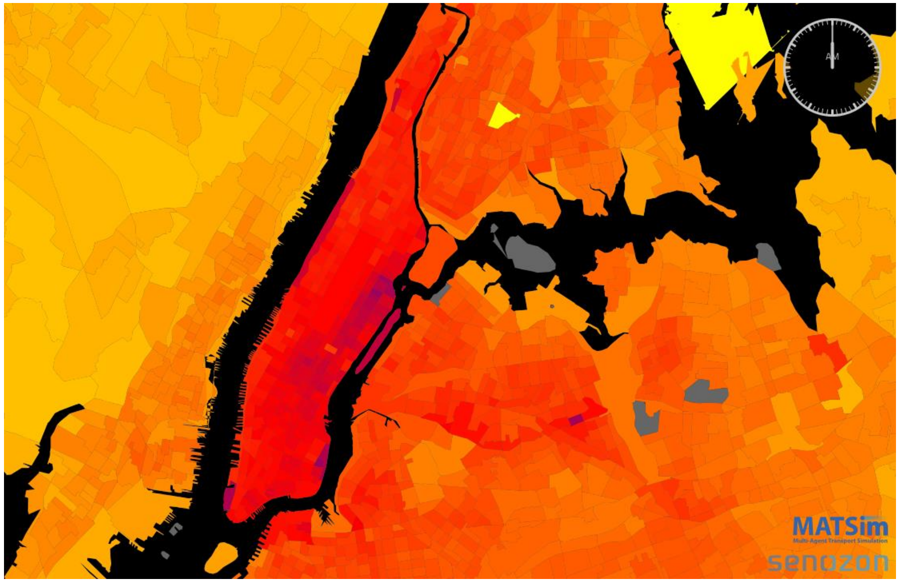
Car share

Base case



Car share

Policy study



Comparisons

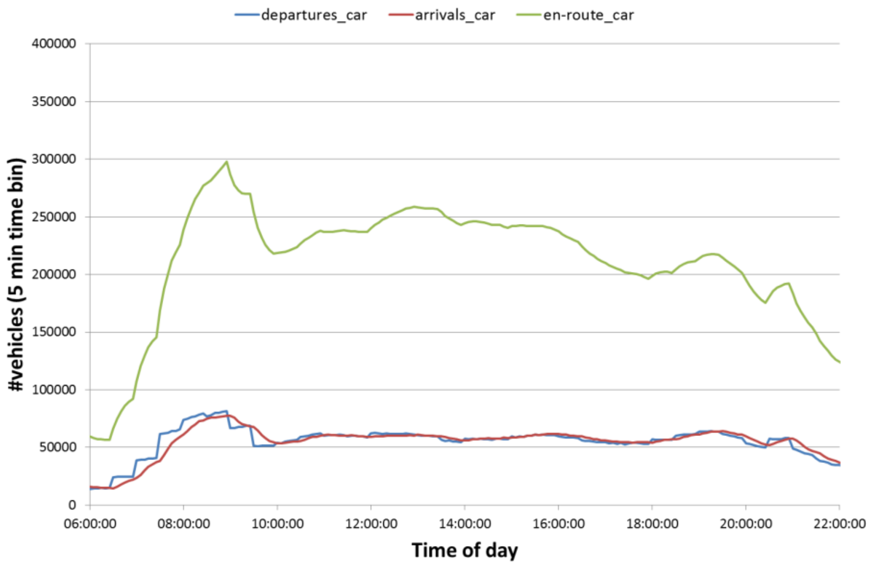
low med. high

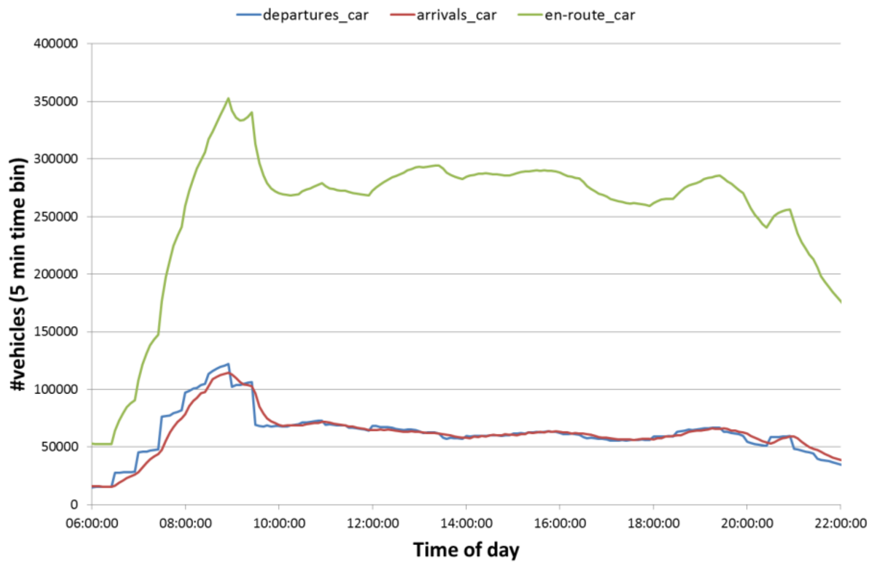
Car trip time distribution

Base case

Car trip time distribution

Policy study





Examples of MATSim Model Analysis

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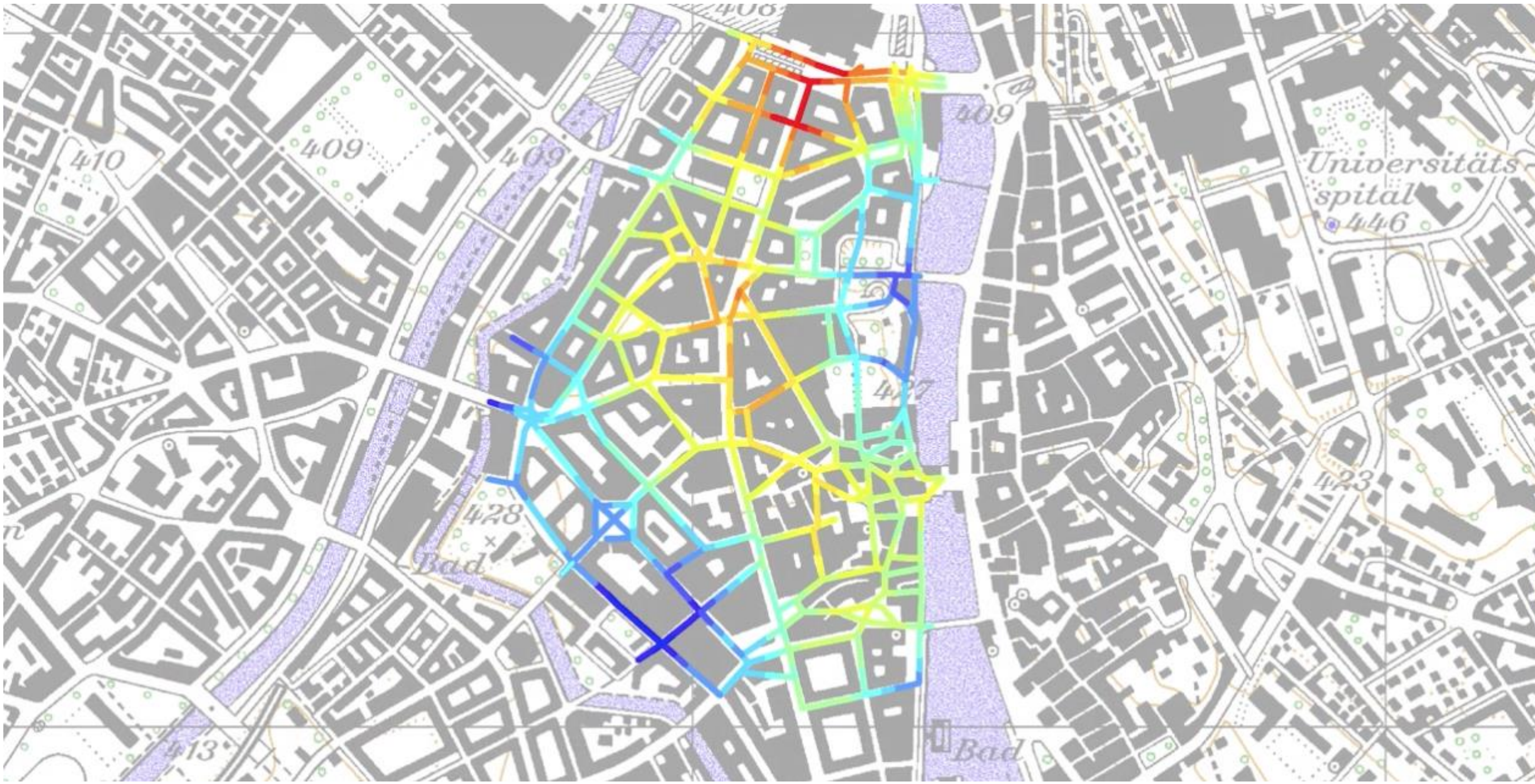
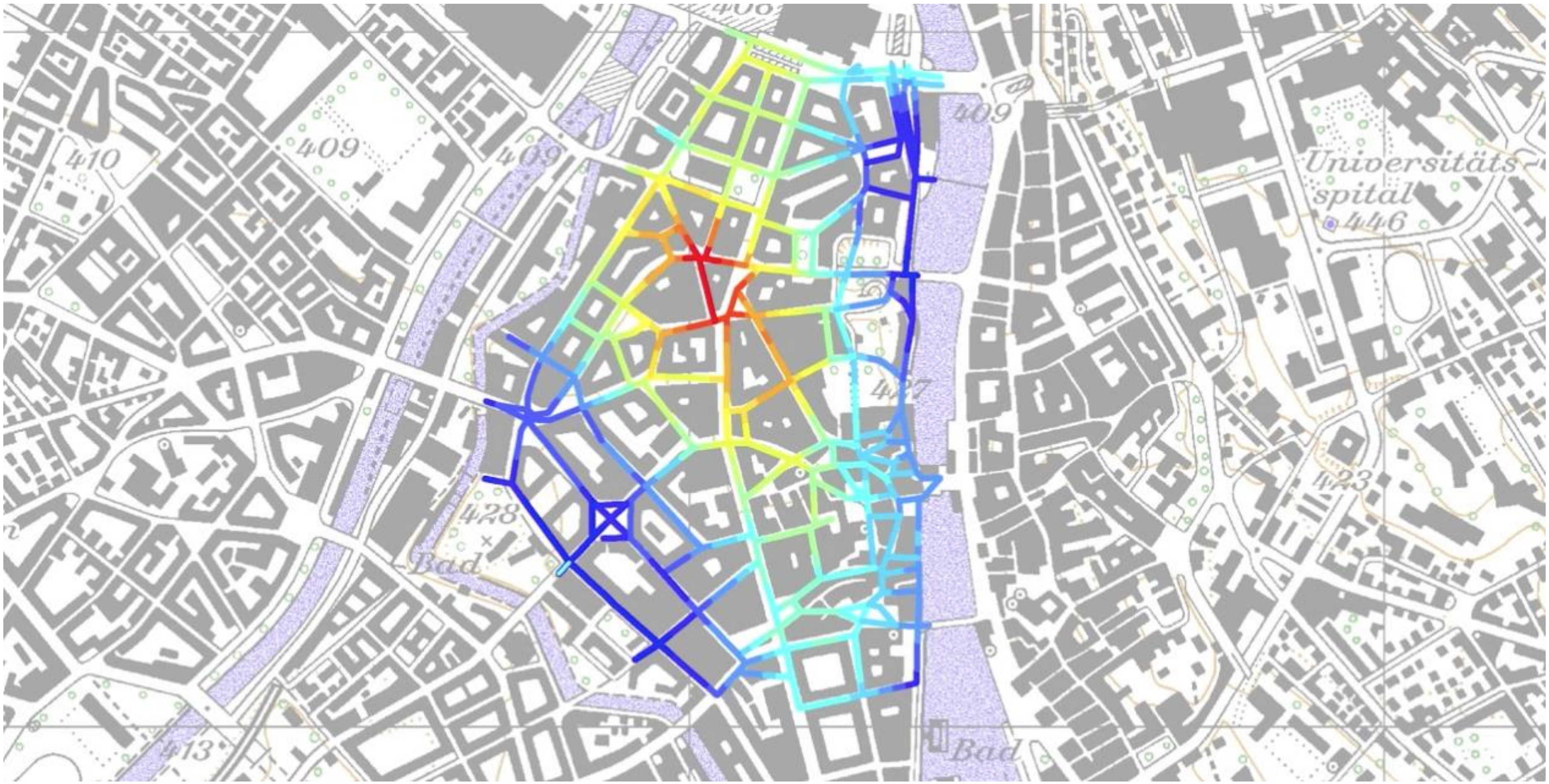
Site Assessment: Pedestrian Frequencies

Number of individual agents per day



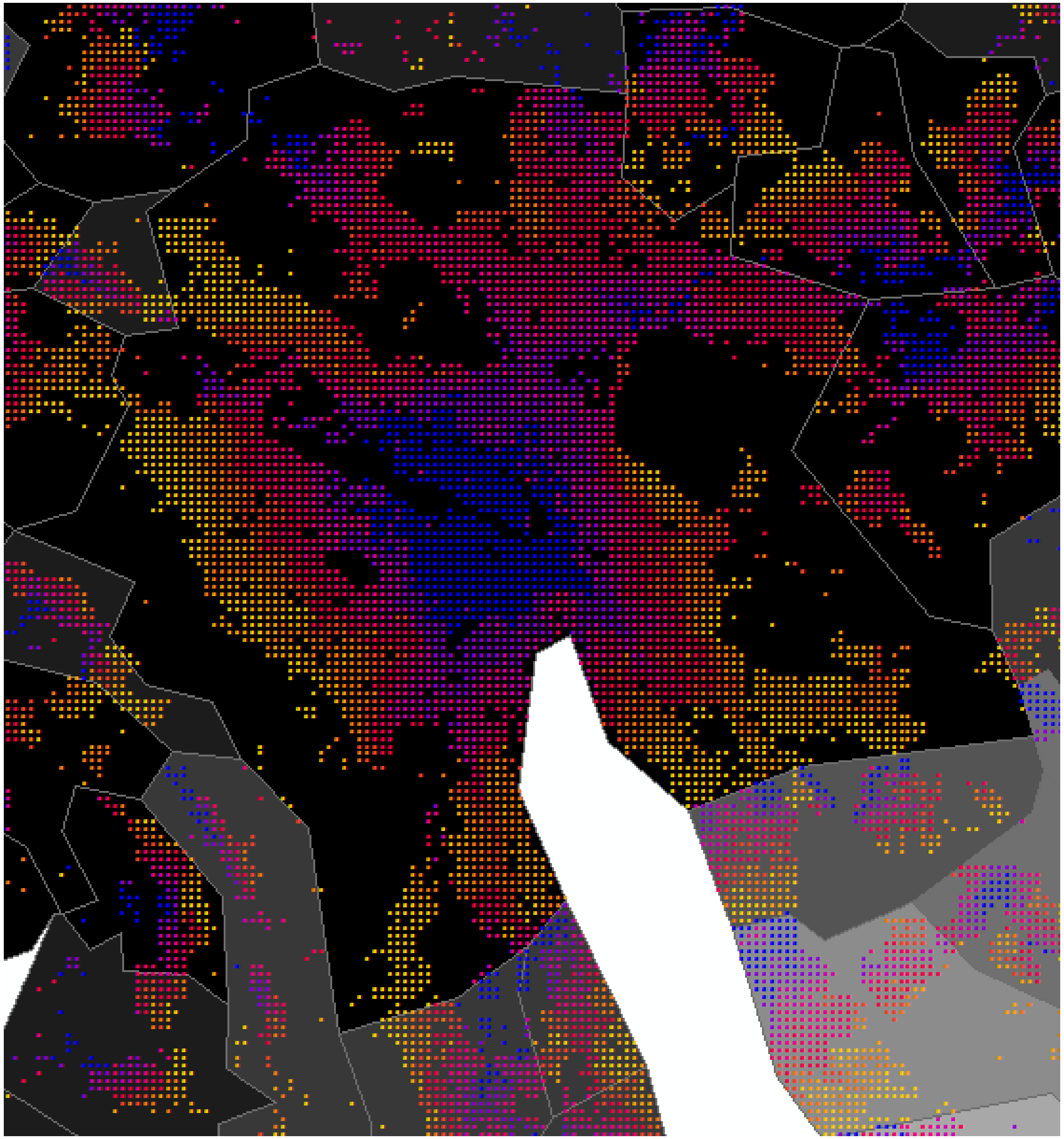
Site Assessment: Pedestrian Frequencies

Number of individual agents per day going shopping

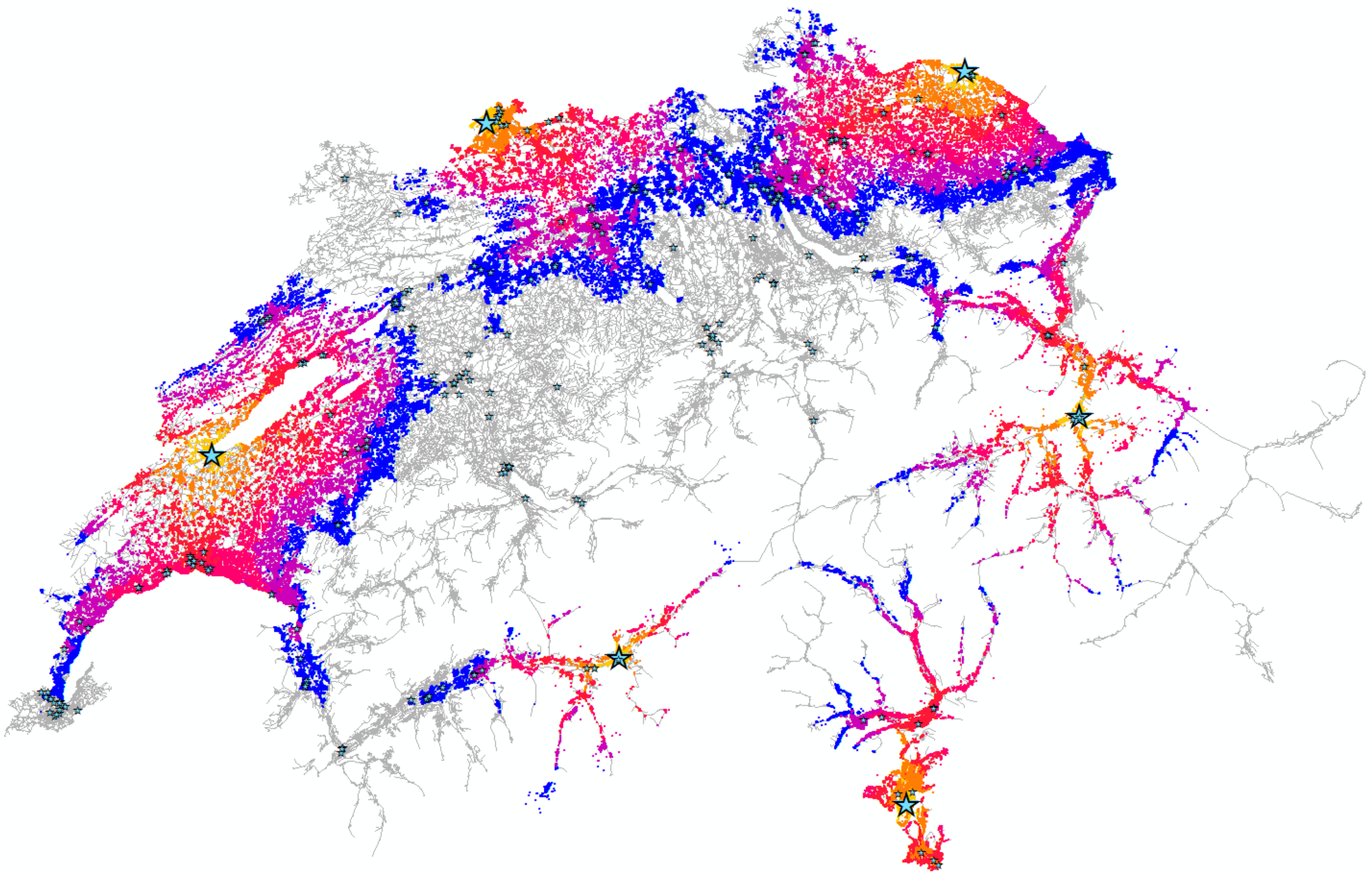


Site Assessment: Pedestrian Frequencies

Example: accessibility of workers

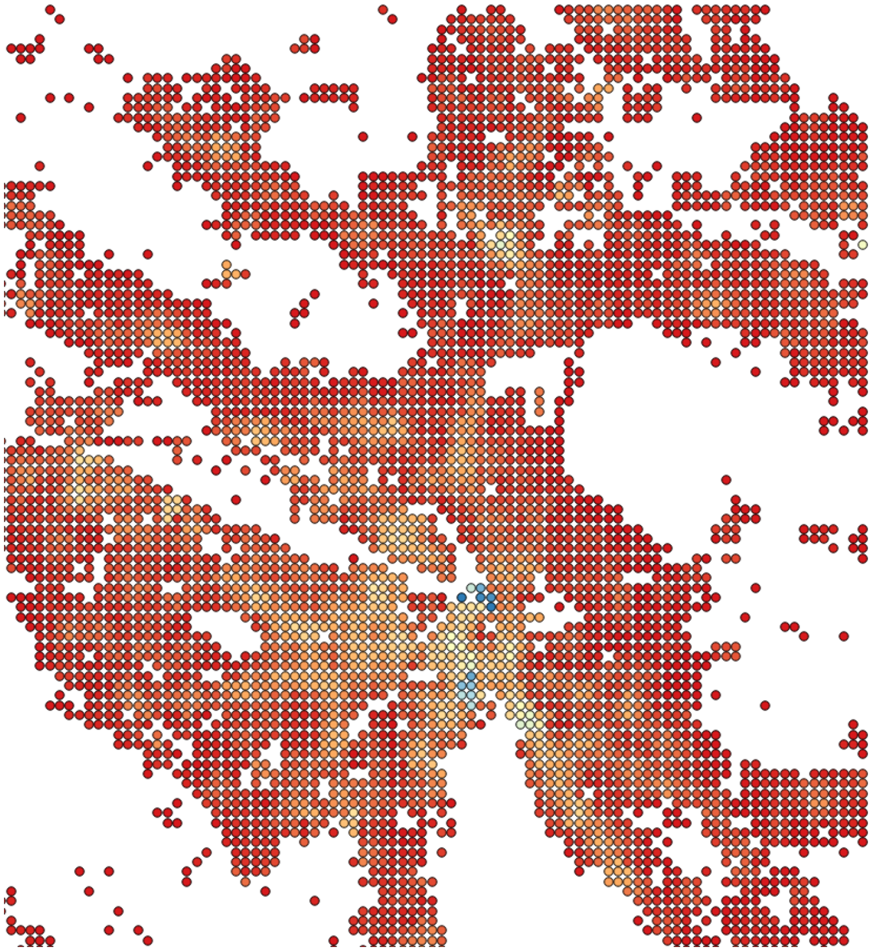


Example: time accessibility



Site Assessment: Estimating Potential

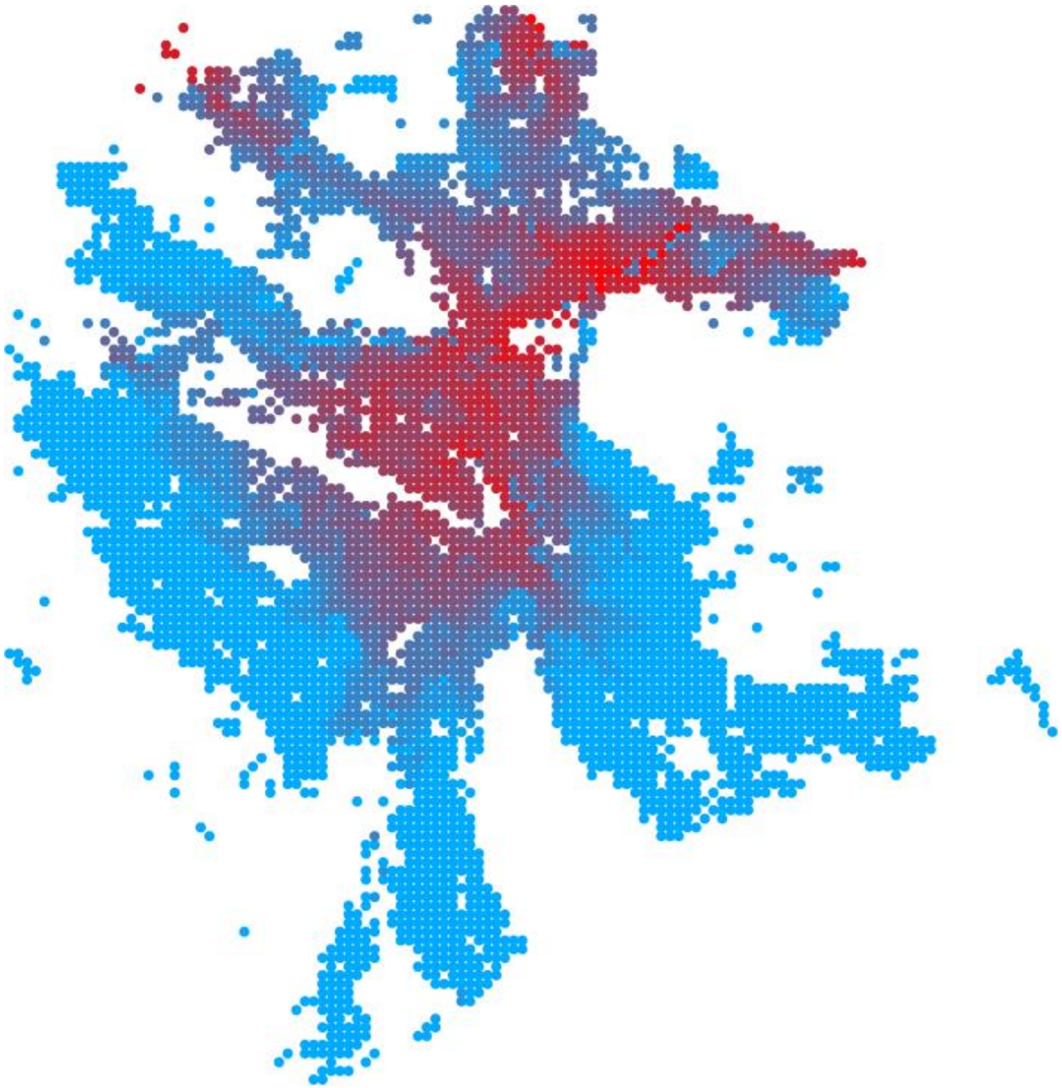
Total potentials
persons with an activity in region



Restricted potentials — only count persons that match some criteria

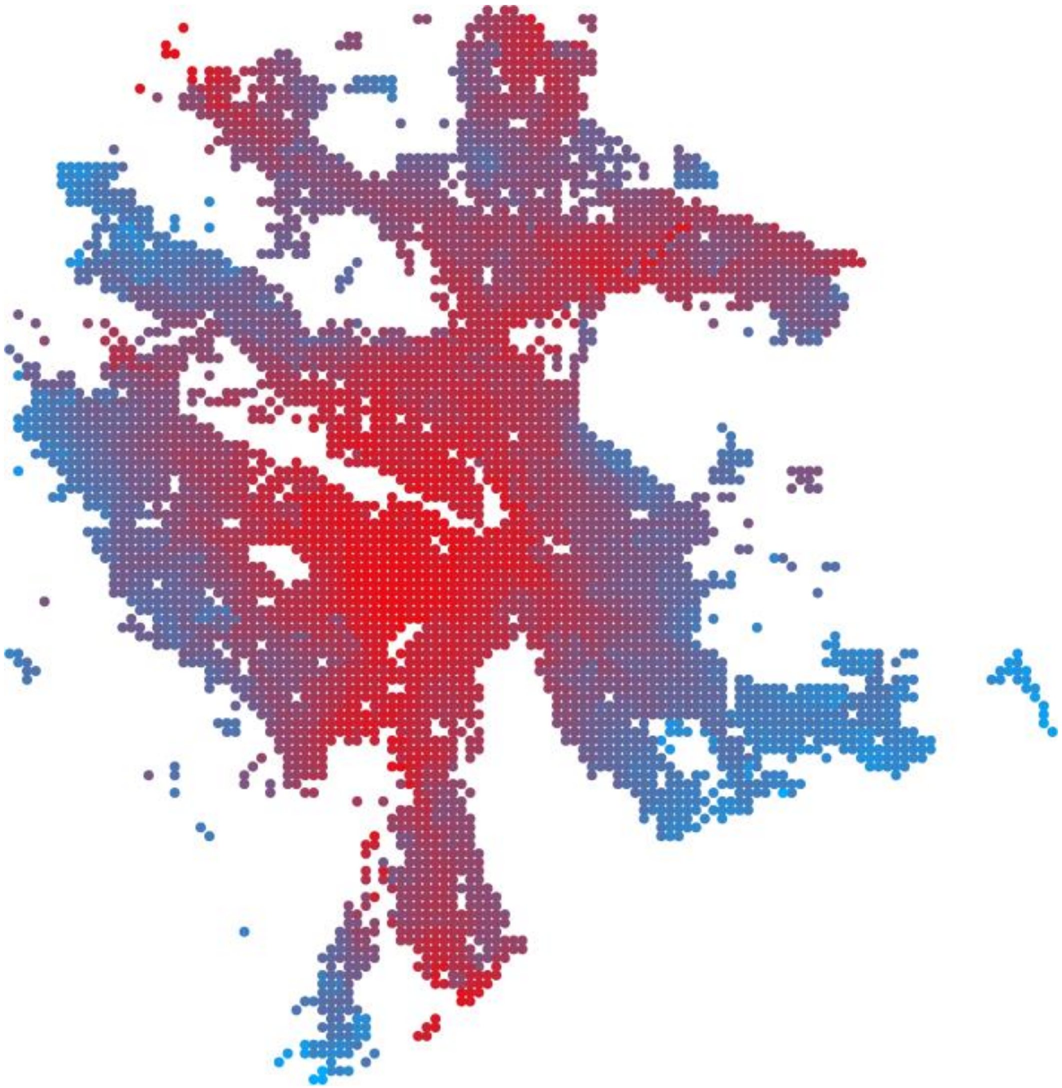
Site Assessment: Reachability

How many persons can reach a cell within 20 minutes with their private car?



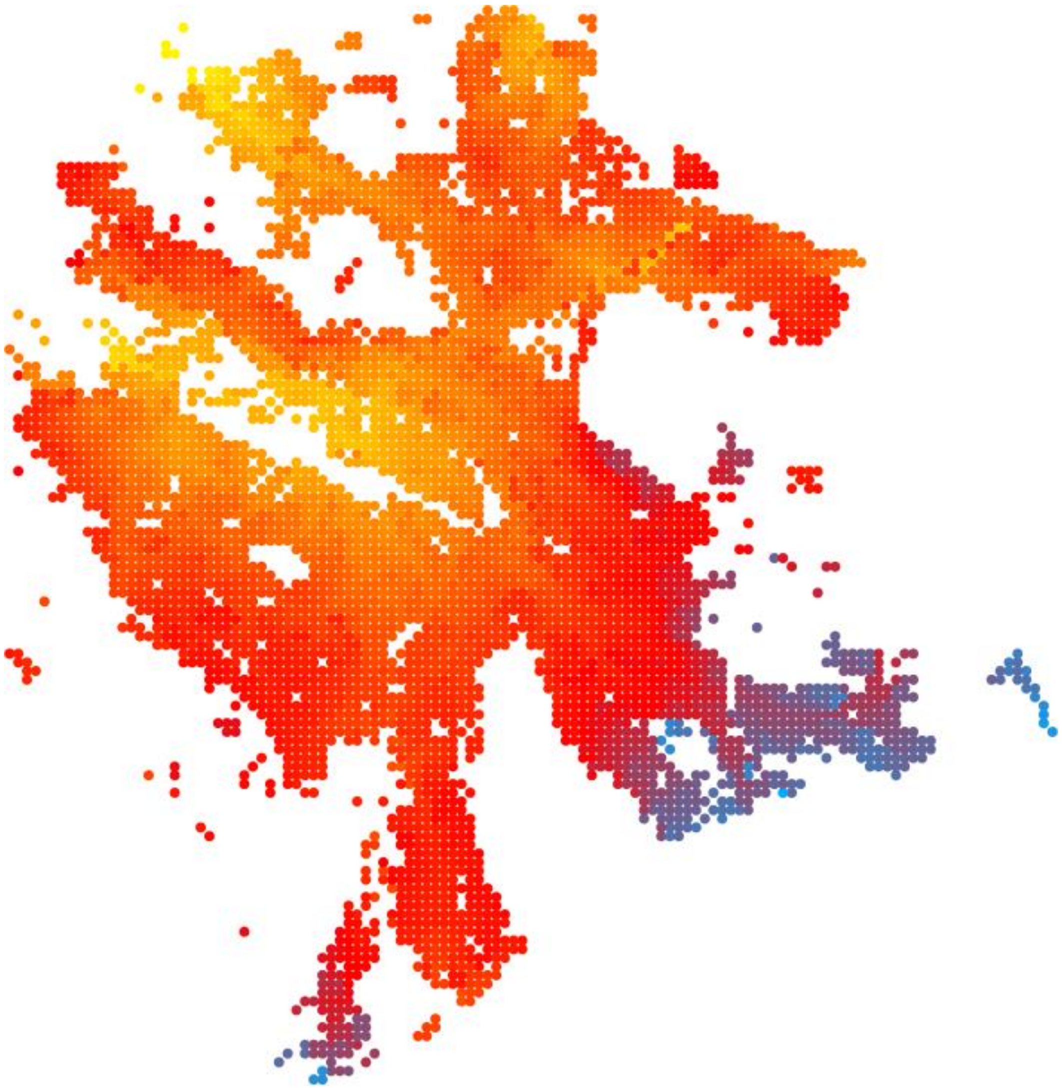
Site Assessment: Reachability

How many persons can reach a cell within 40 minutes with their private car?



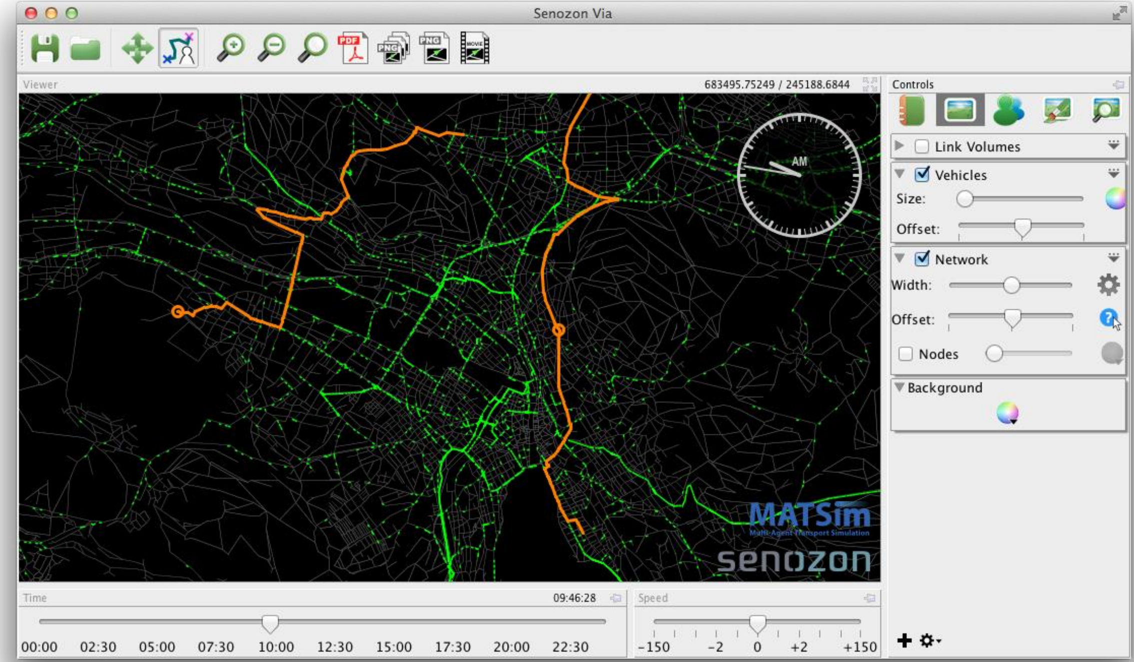
Site Assessment: Reachability

How many persons can reach a cell within 60 minutes with their private car?



Analysis of traffic dynamic with VIA

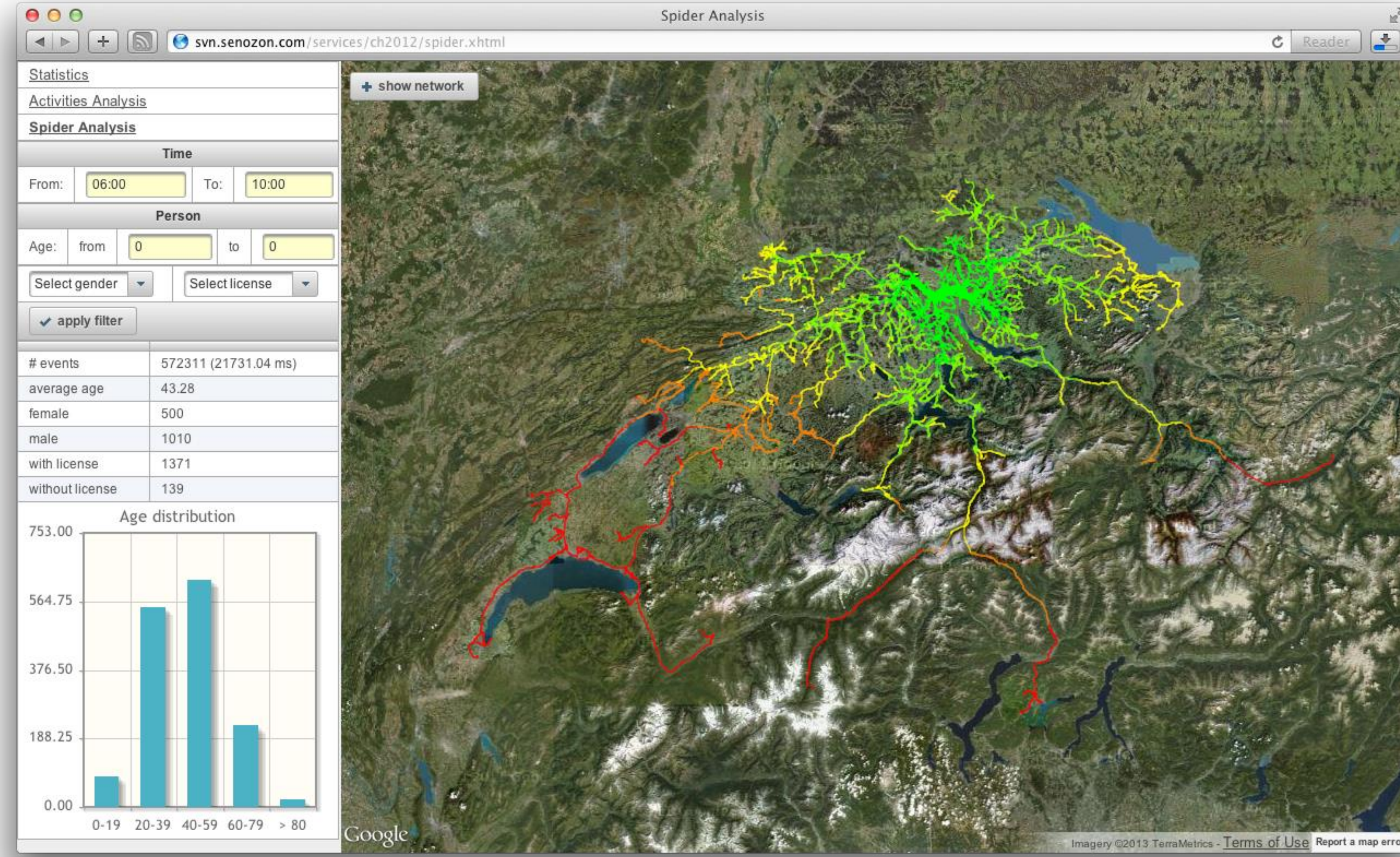
- Dynamic visualization of traffic streams
- Dynamic visualization of activities
- Tracking single agents
- Dynamic representation of traffic volumes
- Dynamic «select link analysis»



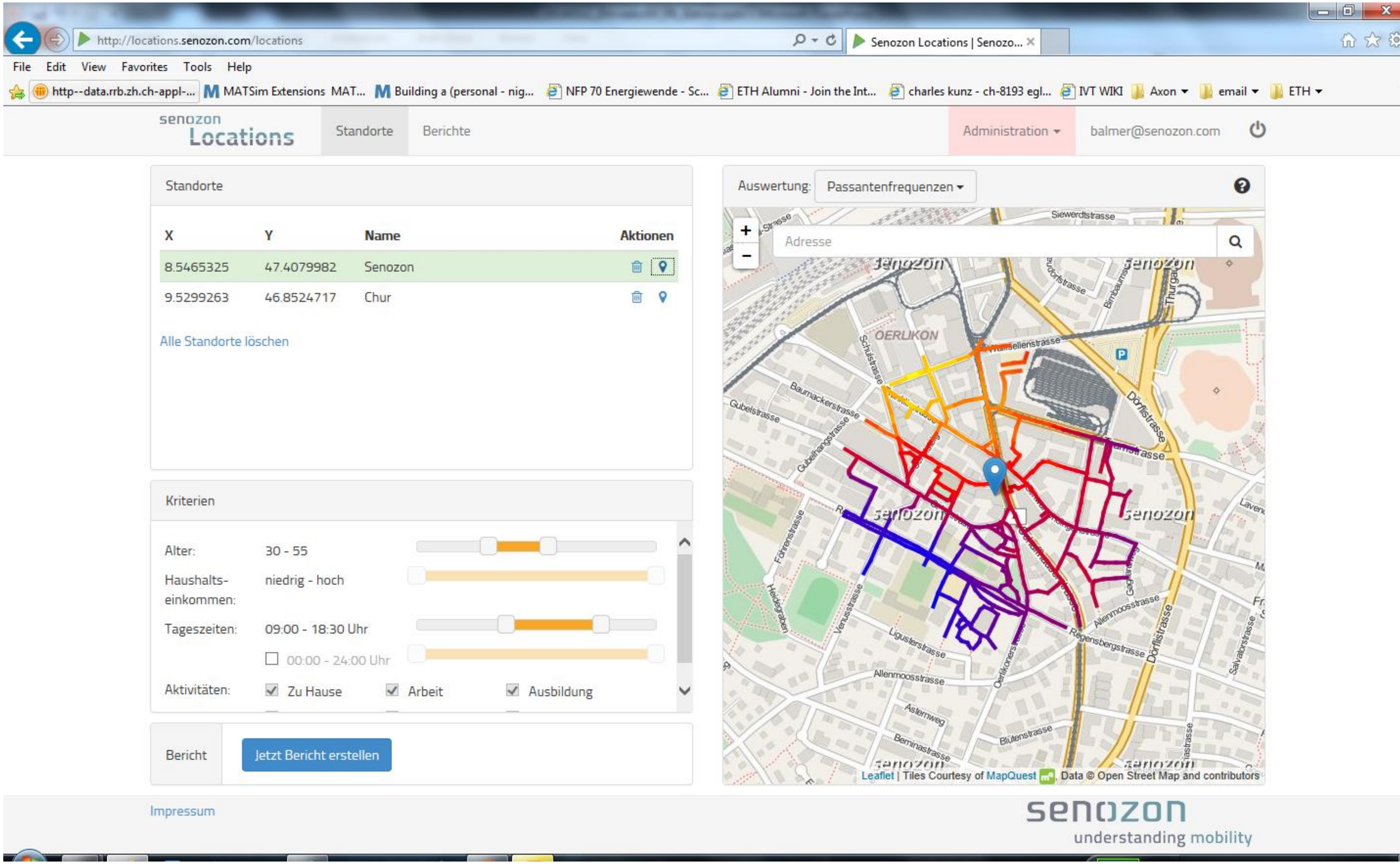
- Dynamic visualization of trips, including public transit vehicles (including waiting time and delays due to boarding / alighting)
- Passenger statistics (boarding / alighting) at stops
- Path-time diagram comparing transit schedules with actual trips
- Raster statistics
- Visualization and analysis of single socio-demographic groups

- Films, Screenshots, etc.…

Online Analysis



Online Analysis: Location Assessment



Discussion

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senozon
understanding mobility

Appendix

One Word about “Micro Simulation”

Senozon @ PB

What is a Microsimulation?

General (econometrics):

A modeling technique that operates at the level of individual units

Traffic:

Models simulating the behavior of individual vehicles within a predefined road network

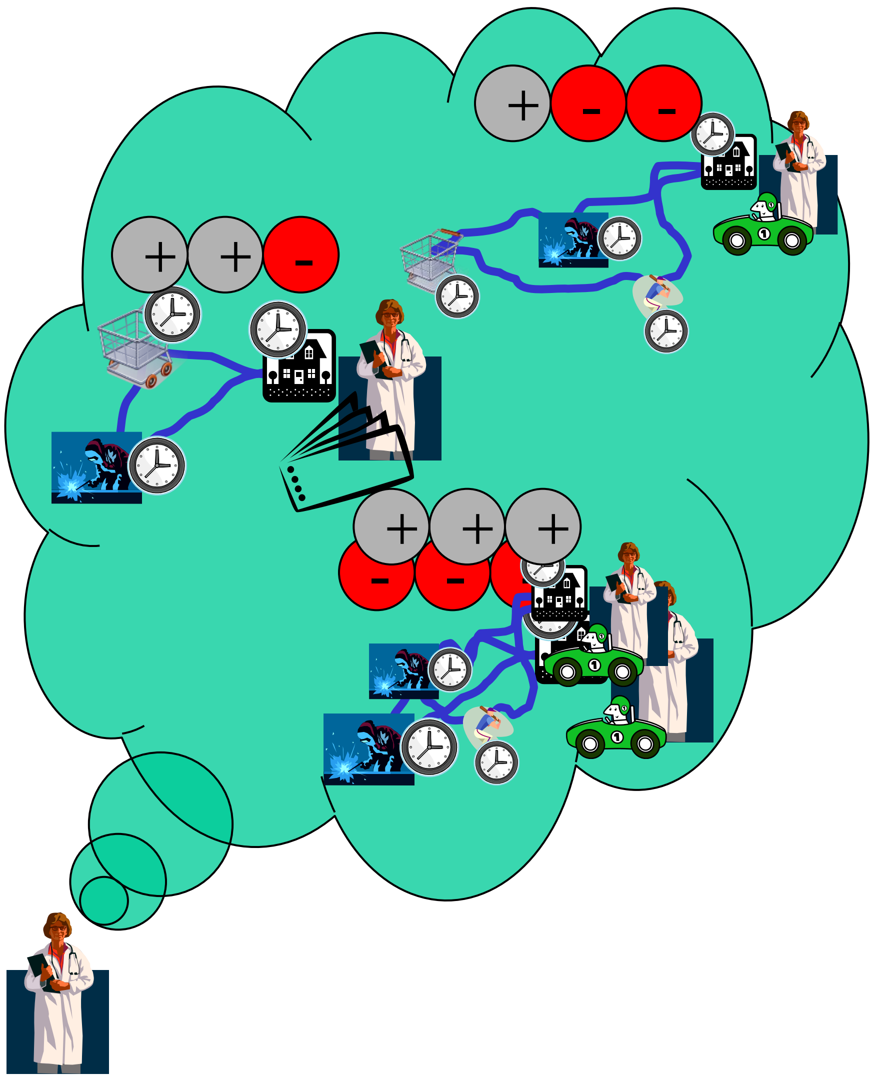
→ MATSim's "Queue model" for traffic flow simulation is microscopic in the sense of persons, vehicles, time and space.

→ MATSim is not (or only to a very limited extent) a traffic micro simulation.

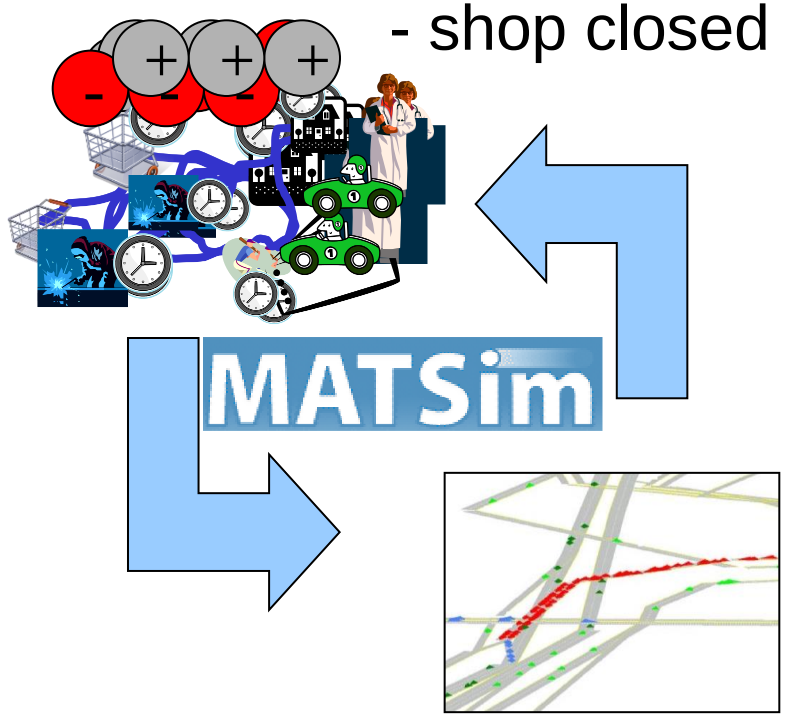
MATSim Relaxation Process

Senozon @ PB

Optimization on the viewpoint of an Agent

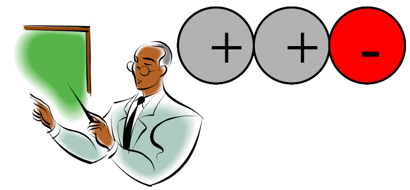


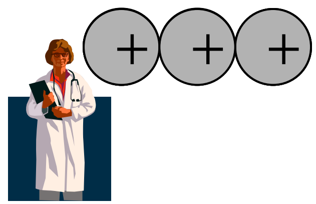
+sports
- congestion
- shop closed



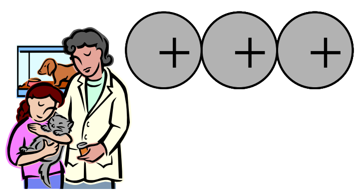
Co-evolutionary algorithm

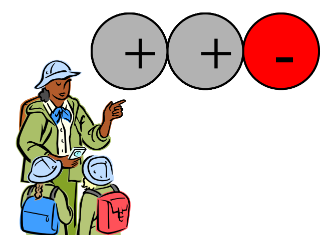
Iteration n





etc.





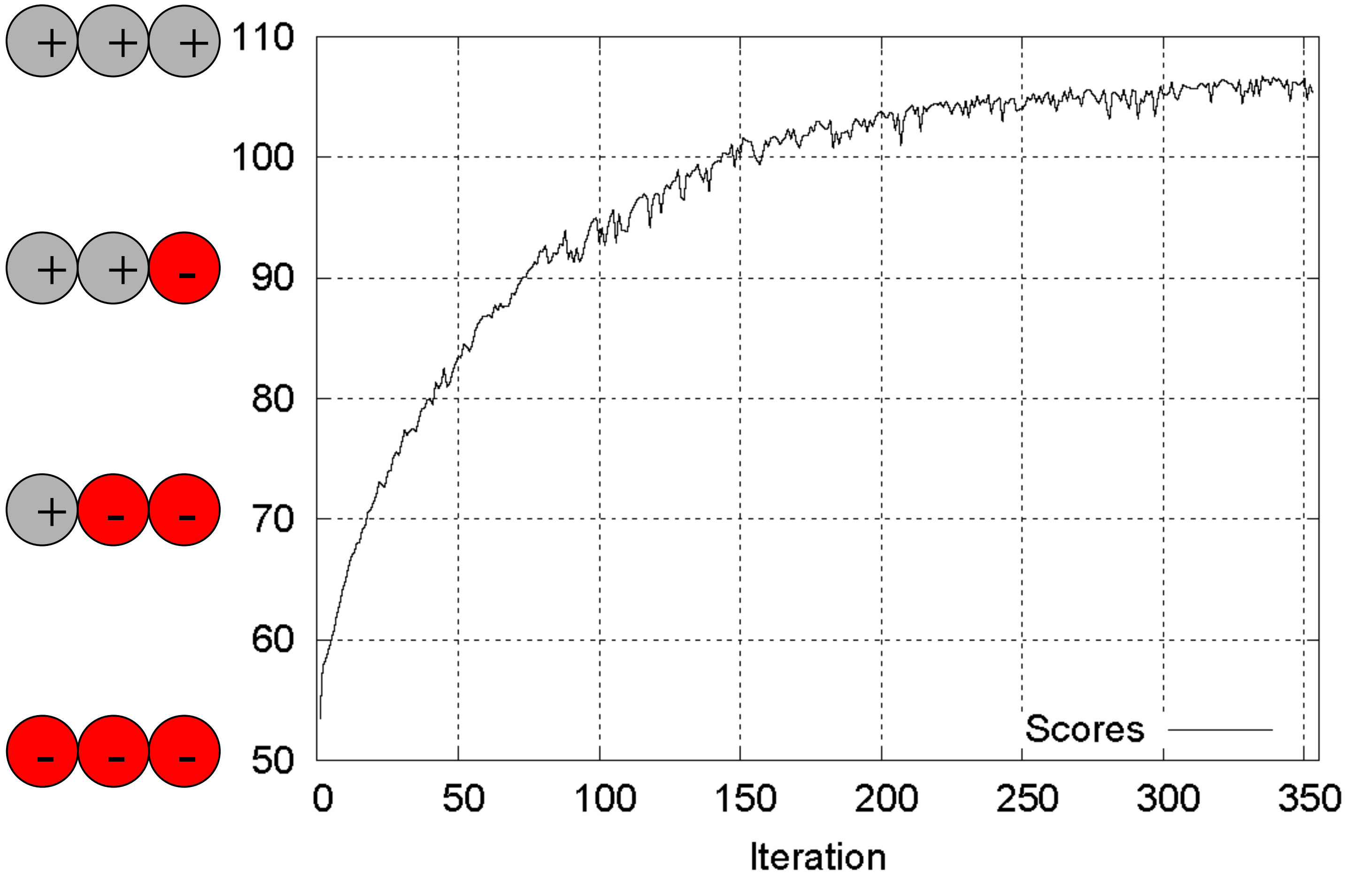
➔ **Stable state**

Example

Scenario:

- Switzerland
- 260‘000 Agents
- chain: h – w – h

Optimization of the whole System



Utility Function

Senozon @ PB

Utility Function

Die Utility Function (Scoring Function, „negative costs“) describes the success of a plan.

It measures:

Utility of traveling

Utility of performing activities

Utility of waiting

etc...

Example

Duration: 24 hours

Agent Smith:

- age = 31 years
- sex = male
- driver’s license = yes
- car availability = always
- employed = yes
- etc...

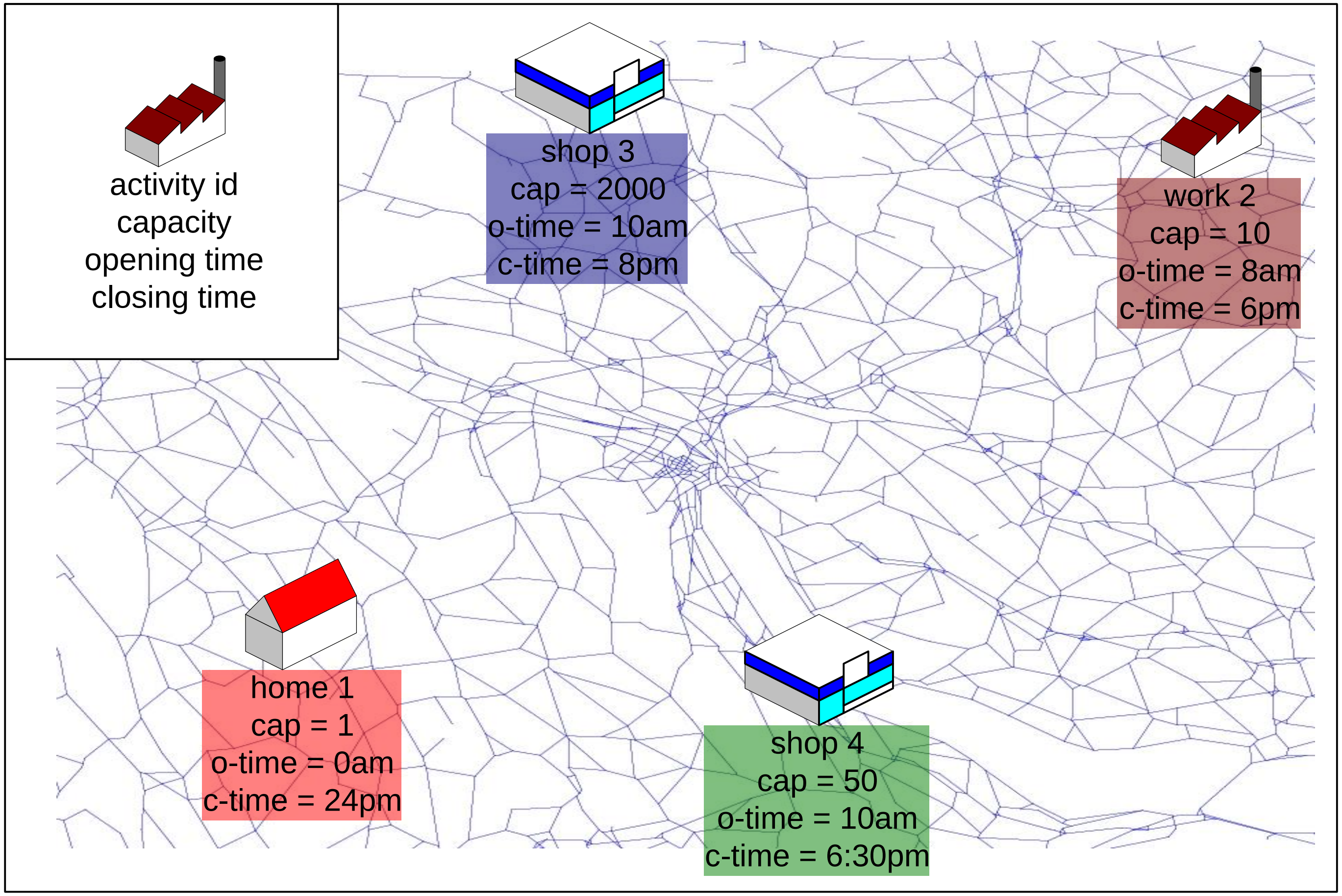
Activity calendar of agent Smith:

- h: 16 hours at home
- w: 8 hours at work
- s: 1 hour for shopping
- l: 4 hours playing pool
- l: 2 hours for sports
- l: 8 hours beer drinking

etc...

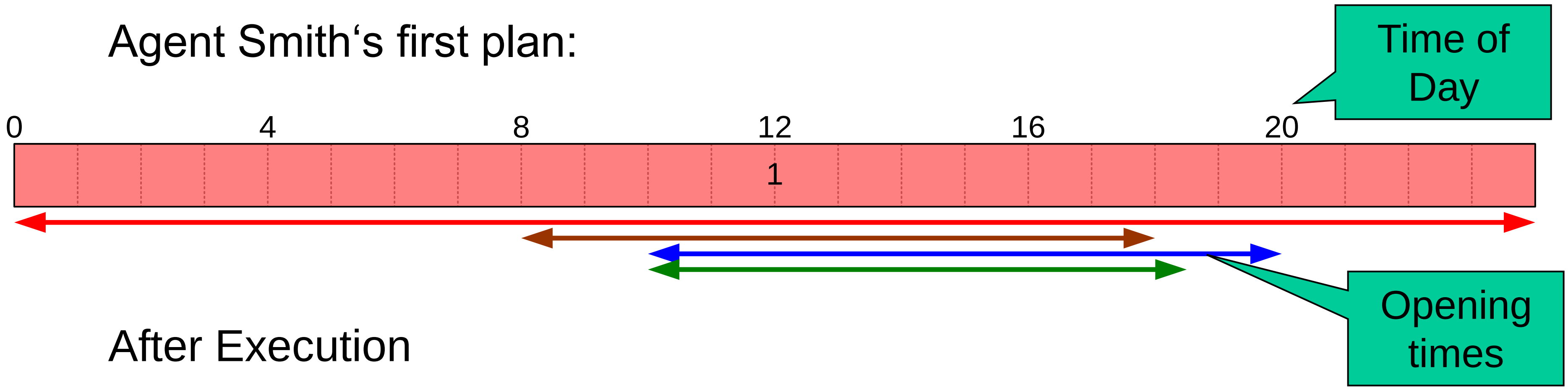
Initial Situation

The mental map of Agent Smith:

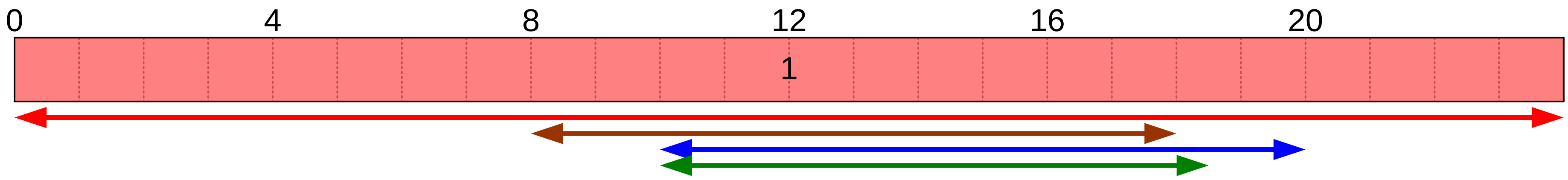


Matsim Iteration

Agent Smith's first plan:



After Execution

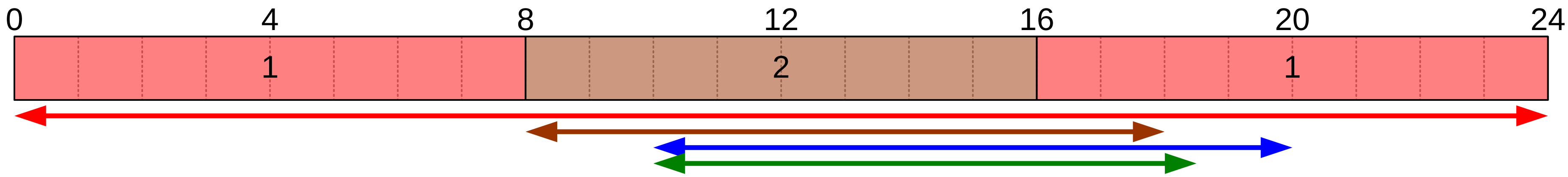


Rating:

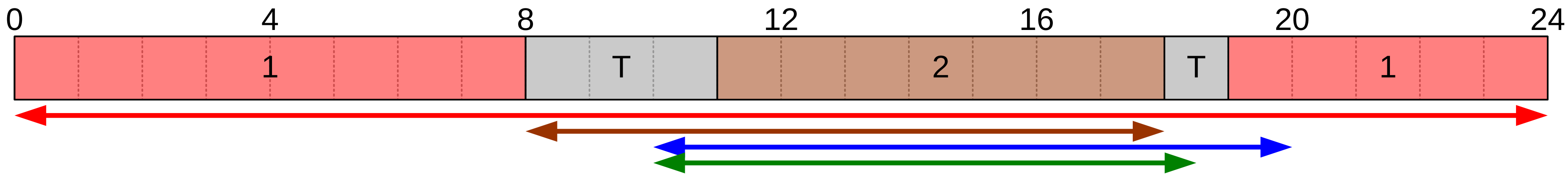
This plan is ok, but the agent does not do a lot…

Matsim Iteration

Agent Smith's second choice:



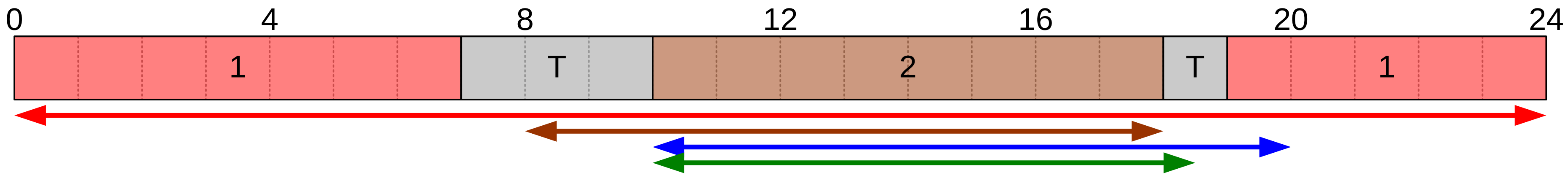
After execution:



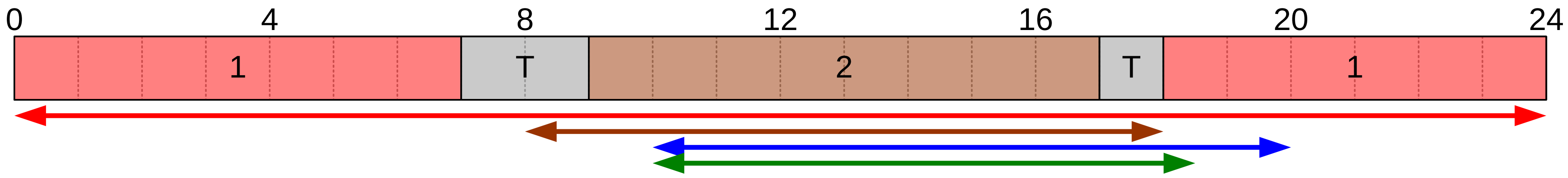
Rating:
Surely, it is better to work a bit, but unfortunately not long enough.
Also the time spent on travel is too much.

Matsim Iteration

Agent Smith's third try:

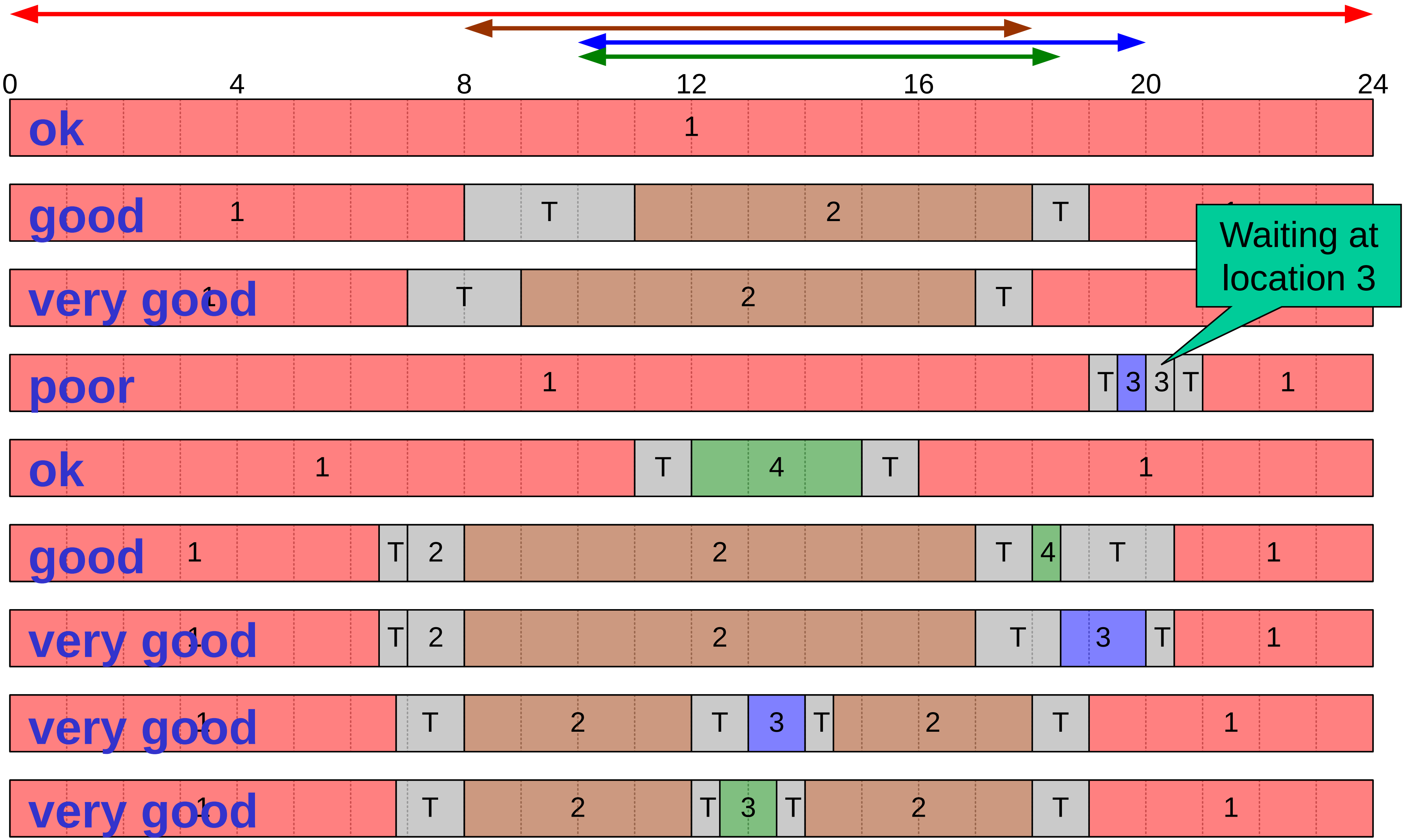


After execution:



Rating:
This already looks quite nice. Less traveling and therefore more time to perform activities.
Agent Smith could also try to add a shopping activity to his day.

Bewertung


0
4
8
12
16
20
24
ok
1
good
1
T
2
T
very good
1
T
2
T
poor
1
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3
3
T
1
Waiting at location 3
ok
1
T
4
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1
good
1
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2
2
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very good
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very good
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very good
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1

Rating → MATSim Utility Function

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

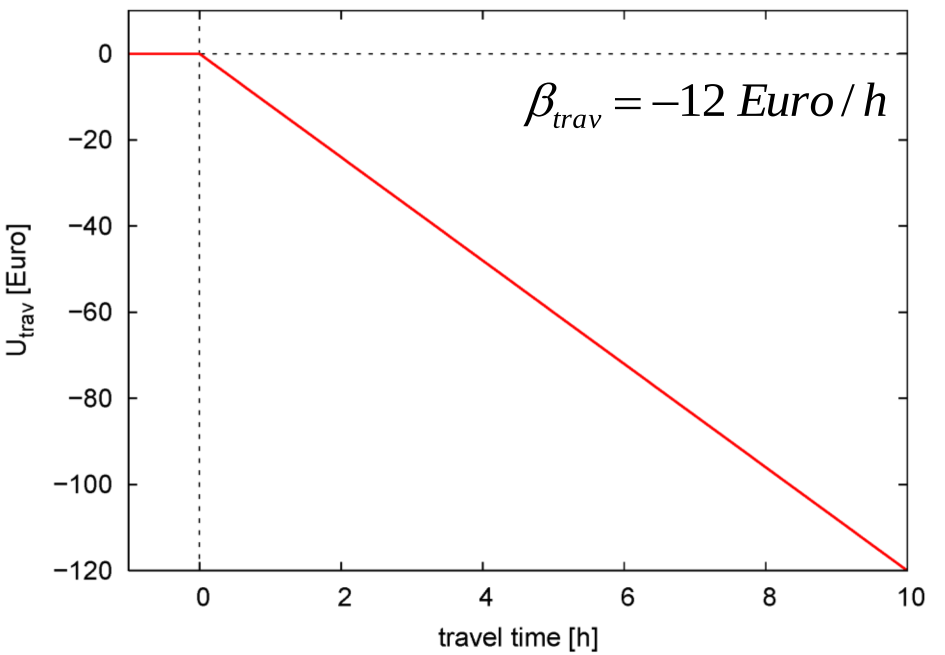
$$U_{act,i} = U_{dur,i} + U_{wait,i} + U_{late.ar,i} + U_{early.dp,i} + U_{short.dur,i}$$

Matsim Utility Function – Utility of Travel

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

$$U_{act,i} = U_{dur,i} + U_{wait,i} + U_{late.ar,i} + U_{early.dp,i} + U_{short.dur,i}$$

$$U_{trav,i-1,i} = \begin{cases} \beta_{trav} \cdot t_{trav,i-1,i} & if \;\; t_{trav,i-1,i} \geq 0 \\ 0 & else \end{cases}$$

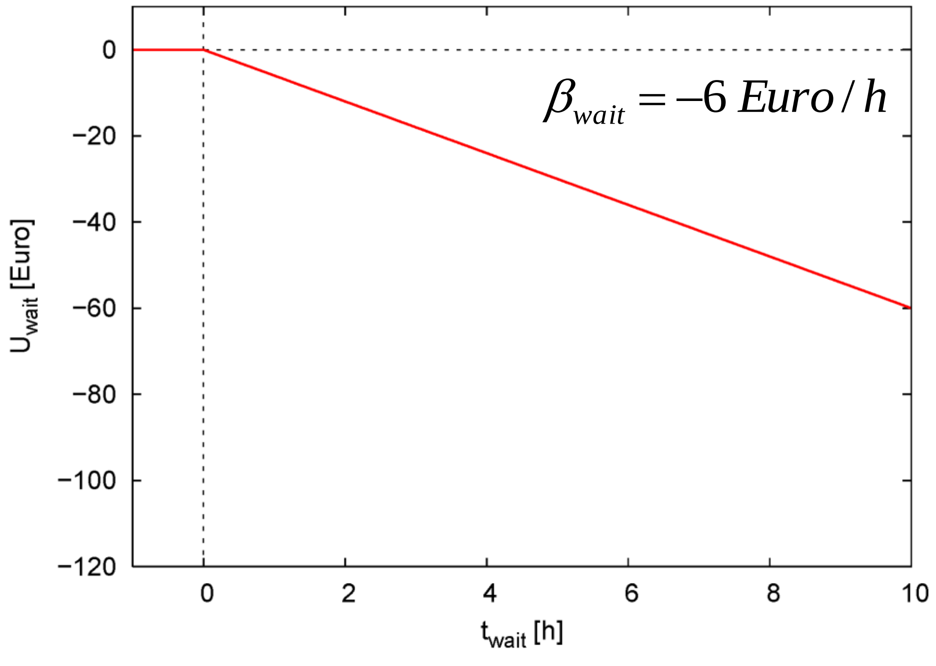


Matsim Utility Function – Utility of Waiting

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

$$U_{act,i} = U_{dur,i} + U_{wait,i} + U_{late.ar,i} + U_{early.dp,i} + U_{short.dur,i}$$

$$U_{wait,i} = \begin{cases} \beta_{wait} \cdot t_{wait,i} & if\ \ t_{wait,i} \geq 0 \\ 0 & else \end{cases}$$

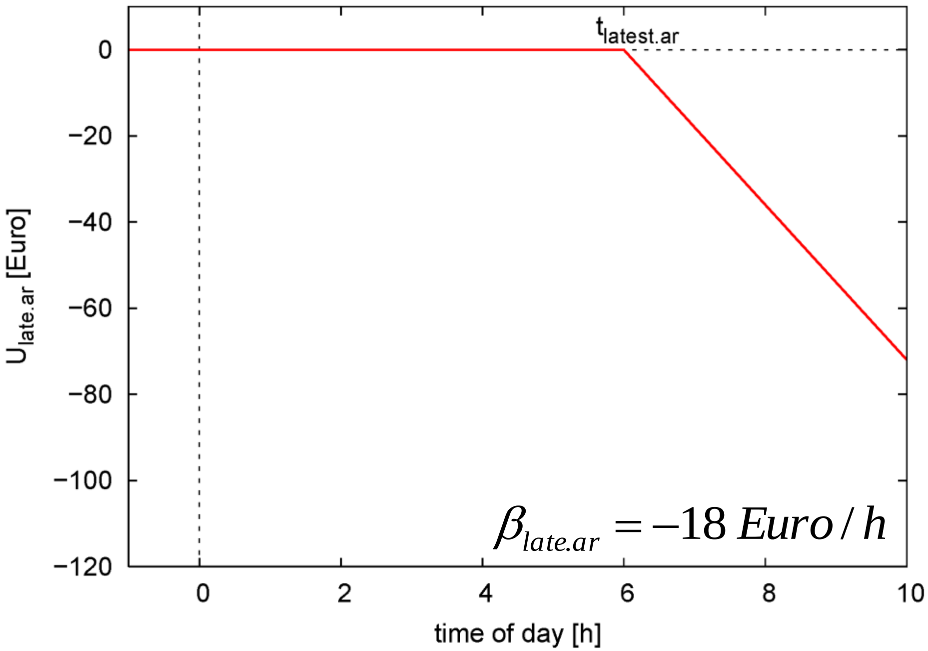


Matsim Utility Function – Utility of Arriving Late

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

$$U_{act,i} = U_{dur,i} + U_{wait,i} + U_{late.ar,i} + U_{early.dp,i} + U_{short.dur,i}$$

$$U_{late.ar,i} = \begin{cases} \beta_{late.ar} \cdot \left(t_{start,i} - t_{latest.ar,i}\right) & if \;\; t_{start,i} \geq t_{latest.ar,i} \\ 0 & else \end{cases}$$

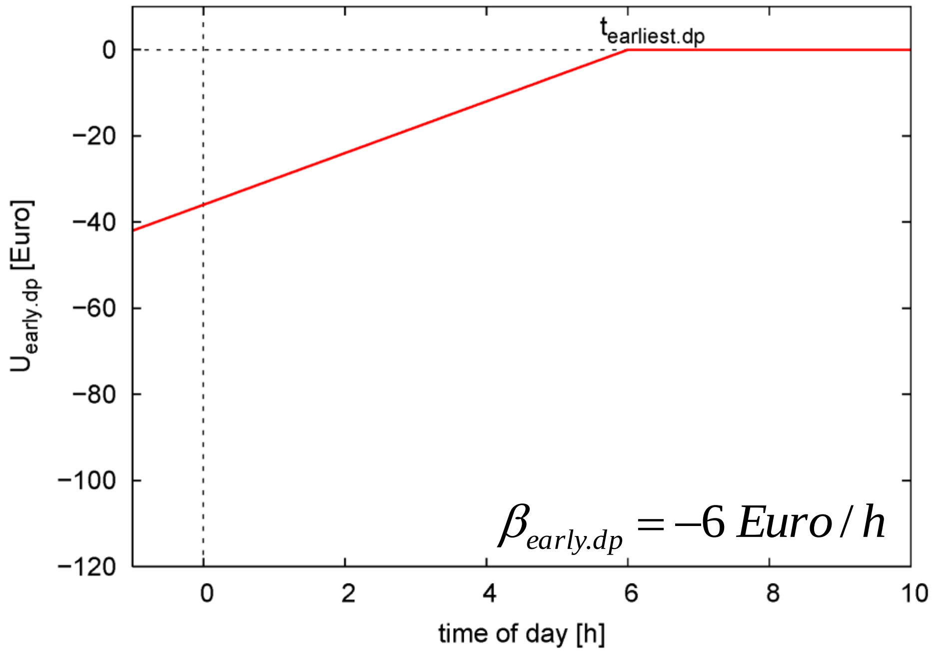


Matsim Utility Function – Utility of Departing Early

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

$$U_{act,i} = U_{dur,i} + U_{wait,i} + U_{late.ar,i} + U_{early.dp,i} + U_{short.dur,i}$$

$$U_{early.dp,i} = \begin{cases} \beta_{early.dp} \cdot \left(t_{earliest.dp,i} - t_{end,i}\right) & if \;\; t_{end,i} \le t_{earliest.dp,i} \\ 0 & else \end{cases}$$

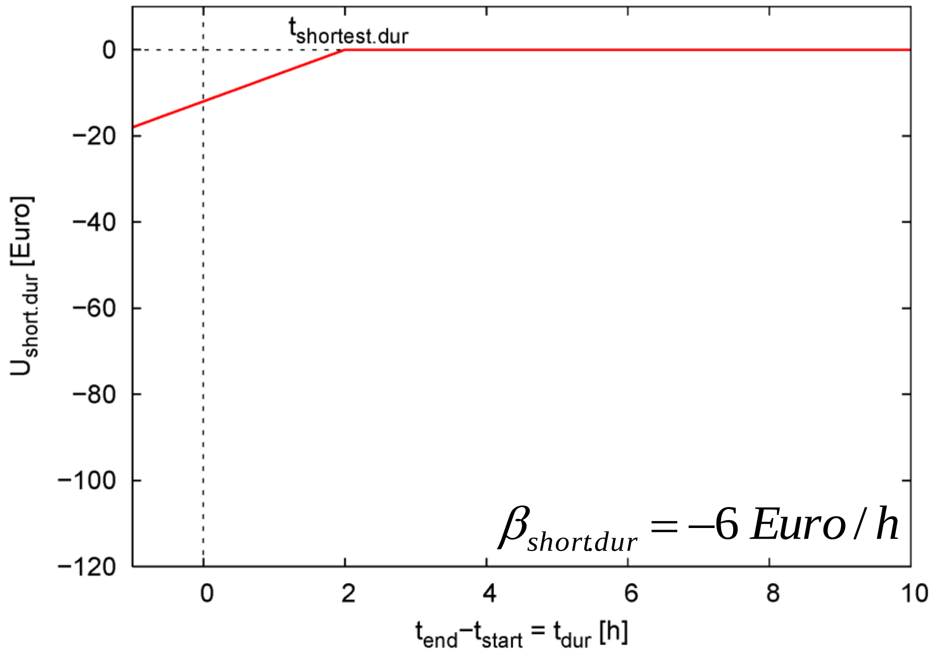


Matsim Utility Function – Utility of Performing an Activity

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

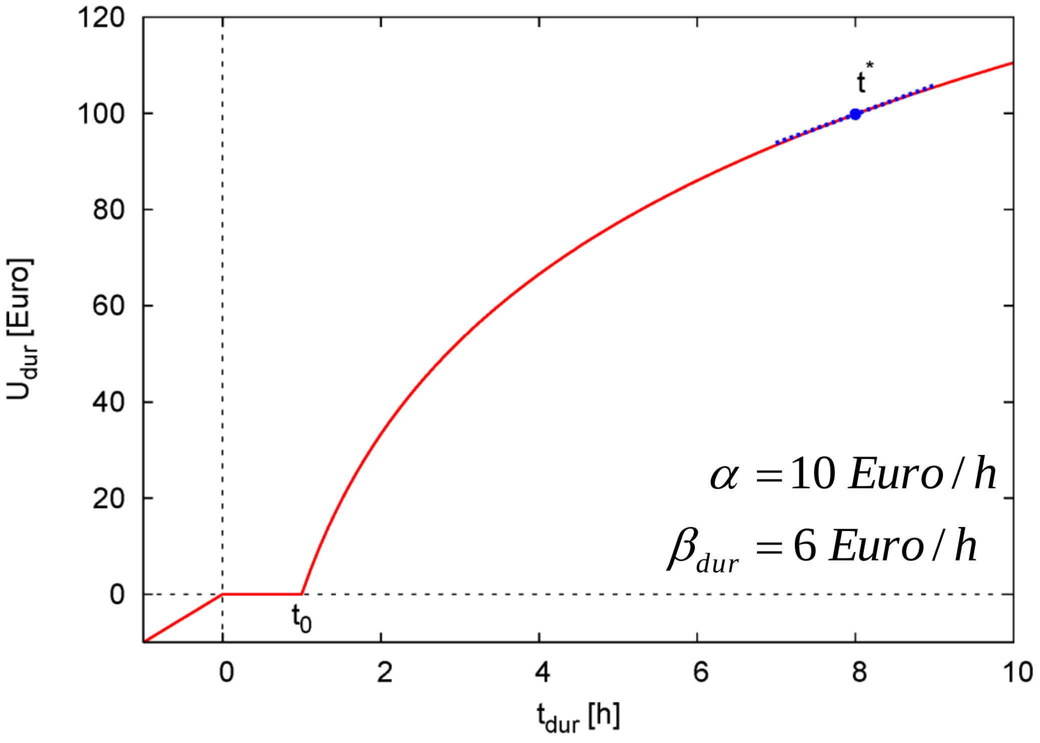
$$U_{act,i} = U_{dur,i} + U_{wait,i} + U_{late.ar,i} + U_{early.dp,i} + U_{short.dur,i}$$

$$U_{short.dur,i} = \begin{cases} \beta_{short.dur} \cdot \left(t_{shortest.dur,i} - \left(t_{end,i} - t_{start,i}\right)\right) & if \; t_{end,i} - t_{start,i} \le t_{shortest.dur,i} \\ 0 & else \end{cases}$$

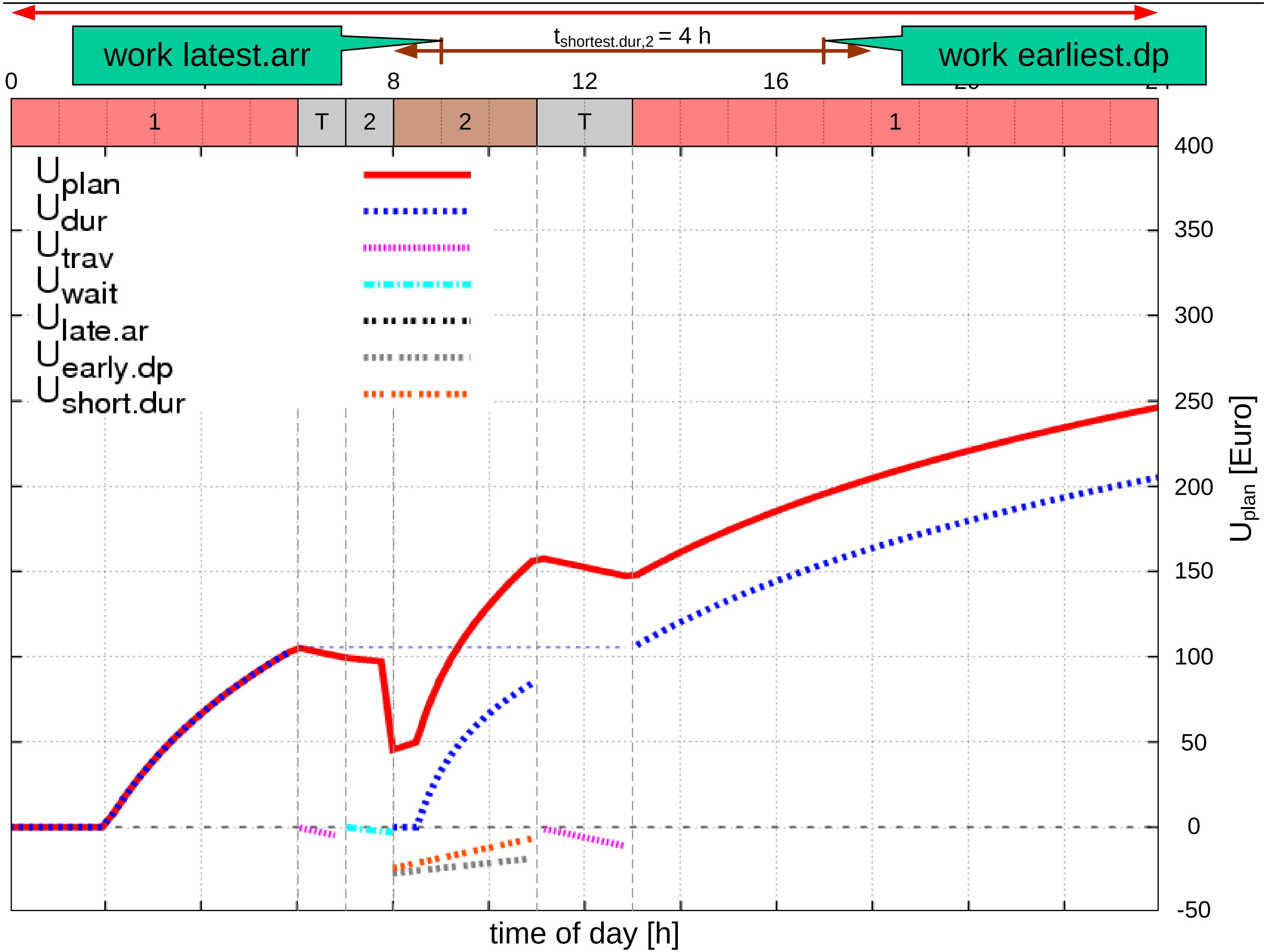


Matsim Utility Function – Utility of Performing an Activity

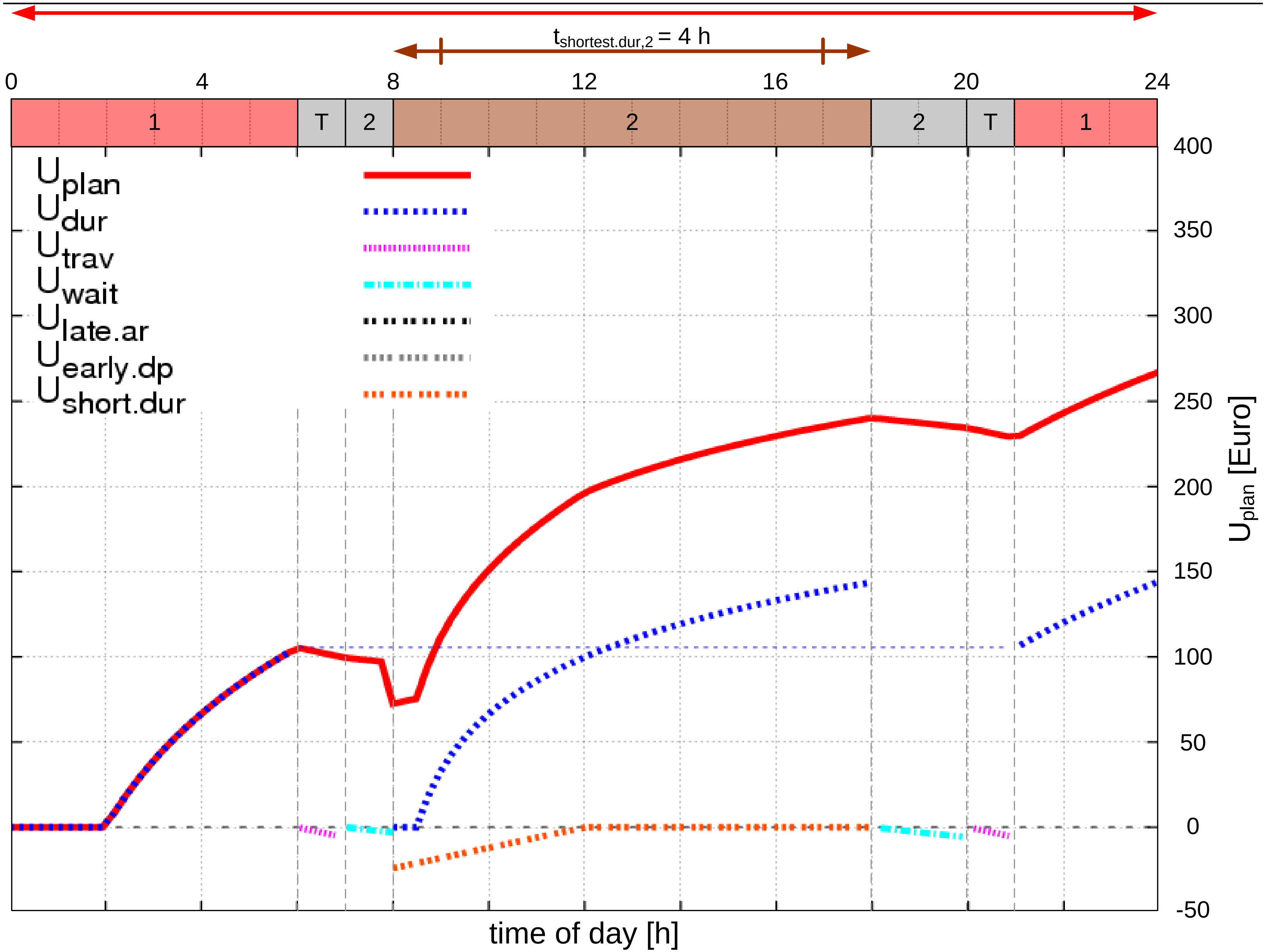
$$U_{dur,i} = \begin{cases} \beta_{dur} \cdot t^* \cdot \ln\left(t_{dur,i} / t_{0,i}\right) & if\ \ t_{0,i} \leq t_{dur,i} \\ 0 & if\ \ 0 \leq t_{dur,i} < t_{0,i} \\ \alpha \cdot t_{dur,i} & else\ (\alpha > 0) \end{cases}$$



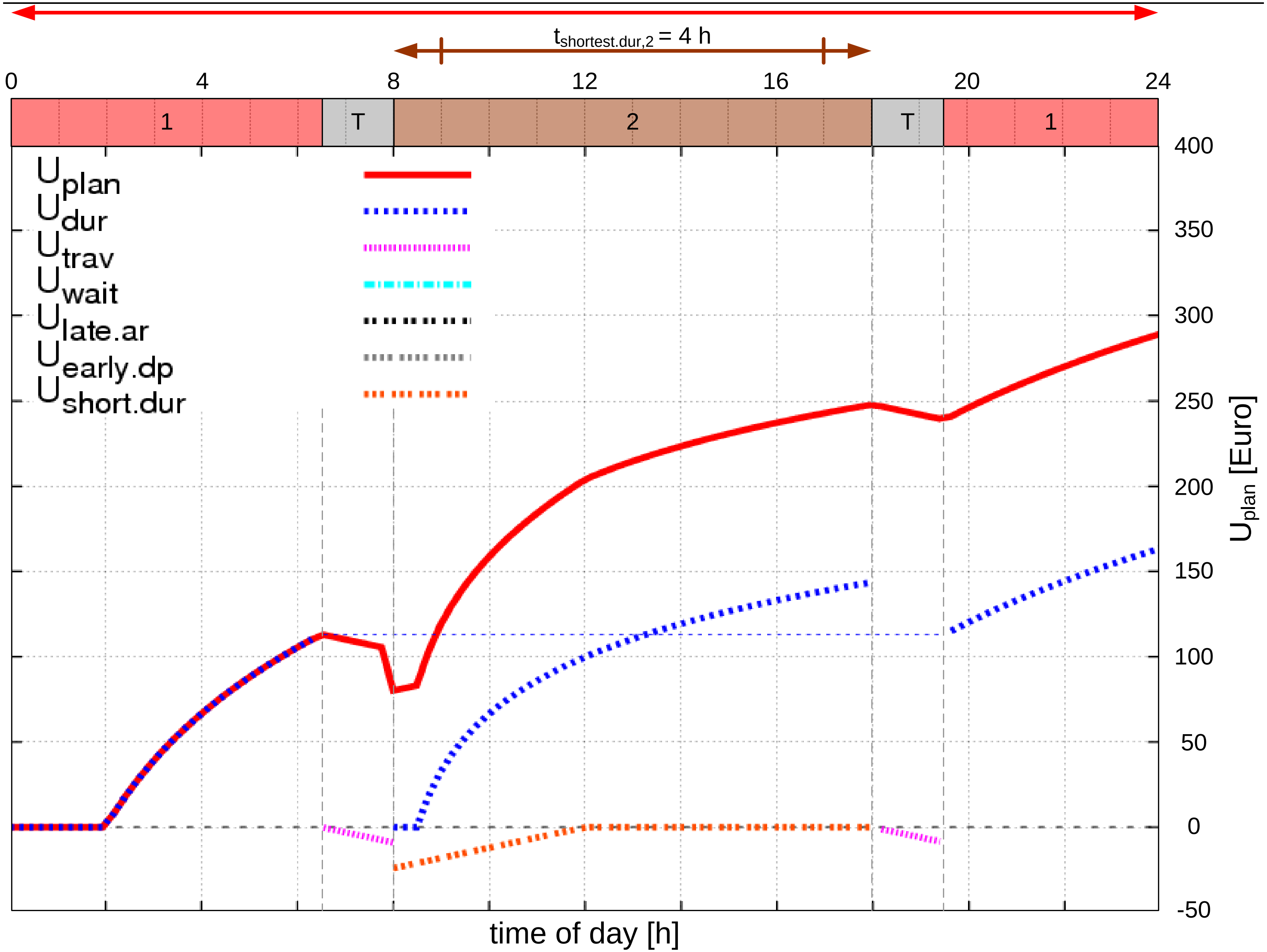
Matsim Utility Function – Example (Home-Work-Home)



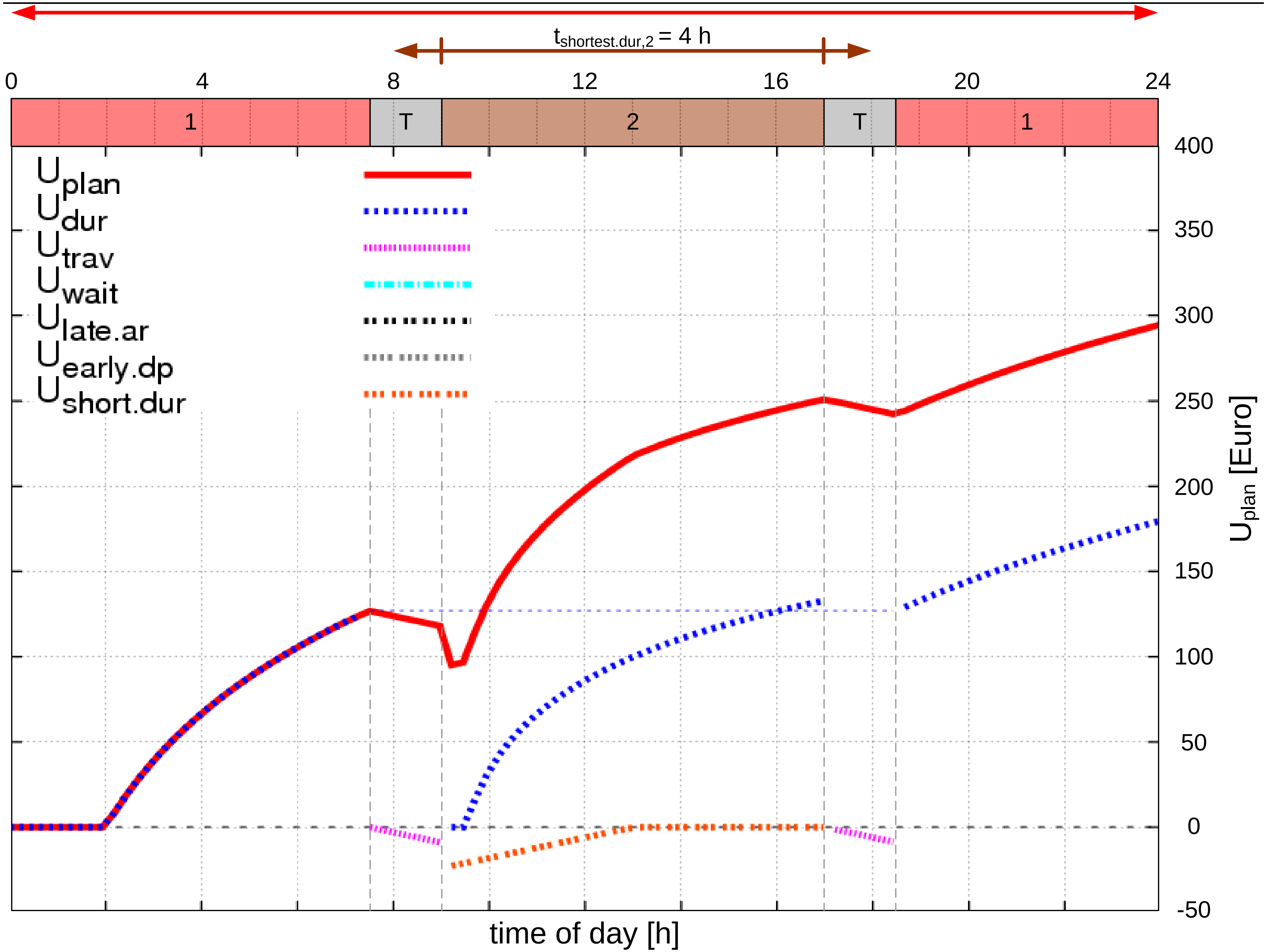
Matsim Utility Function – Example (Home-Work-Home)



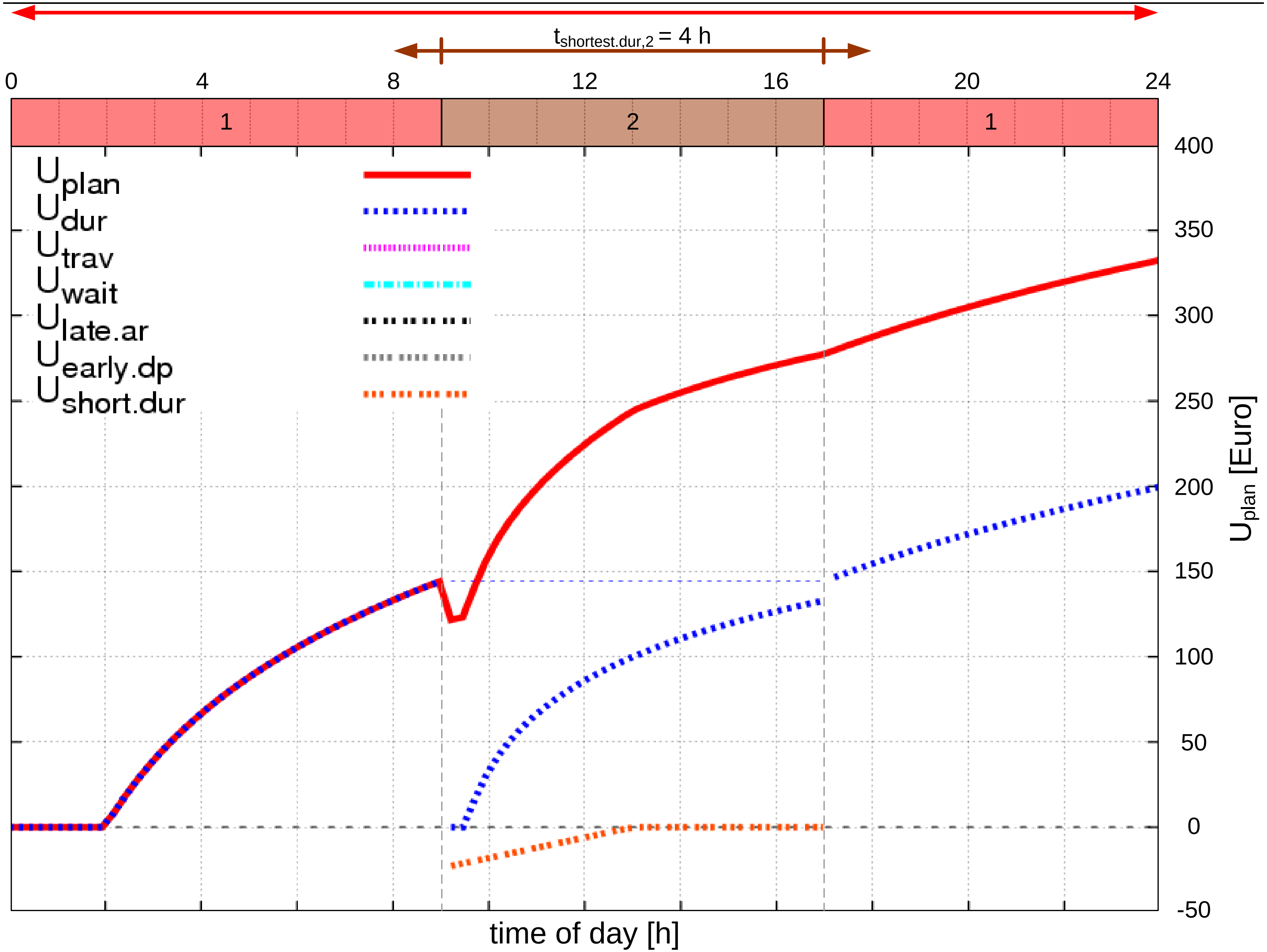
Matsim Utility Function – Example (Home-Work-Home)



Matsim Utility Function – Example (Home-Work-Home)



Matsim Utility Function – Example (Home-Work-Home)



Utility Function: Discussion

- Simple description (sum terms)
- Rating of the whole day (not only parts of it)
- Here:
  U = f(time)
- But in general also extended to:
  U = f(time, money, distance, road pricing, «emotional» costs, etc…)
- General: (generalized negative costs := generalized utility)
- personalized!!!