

# Parking



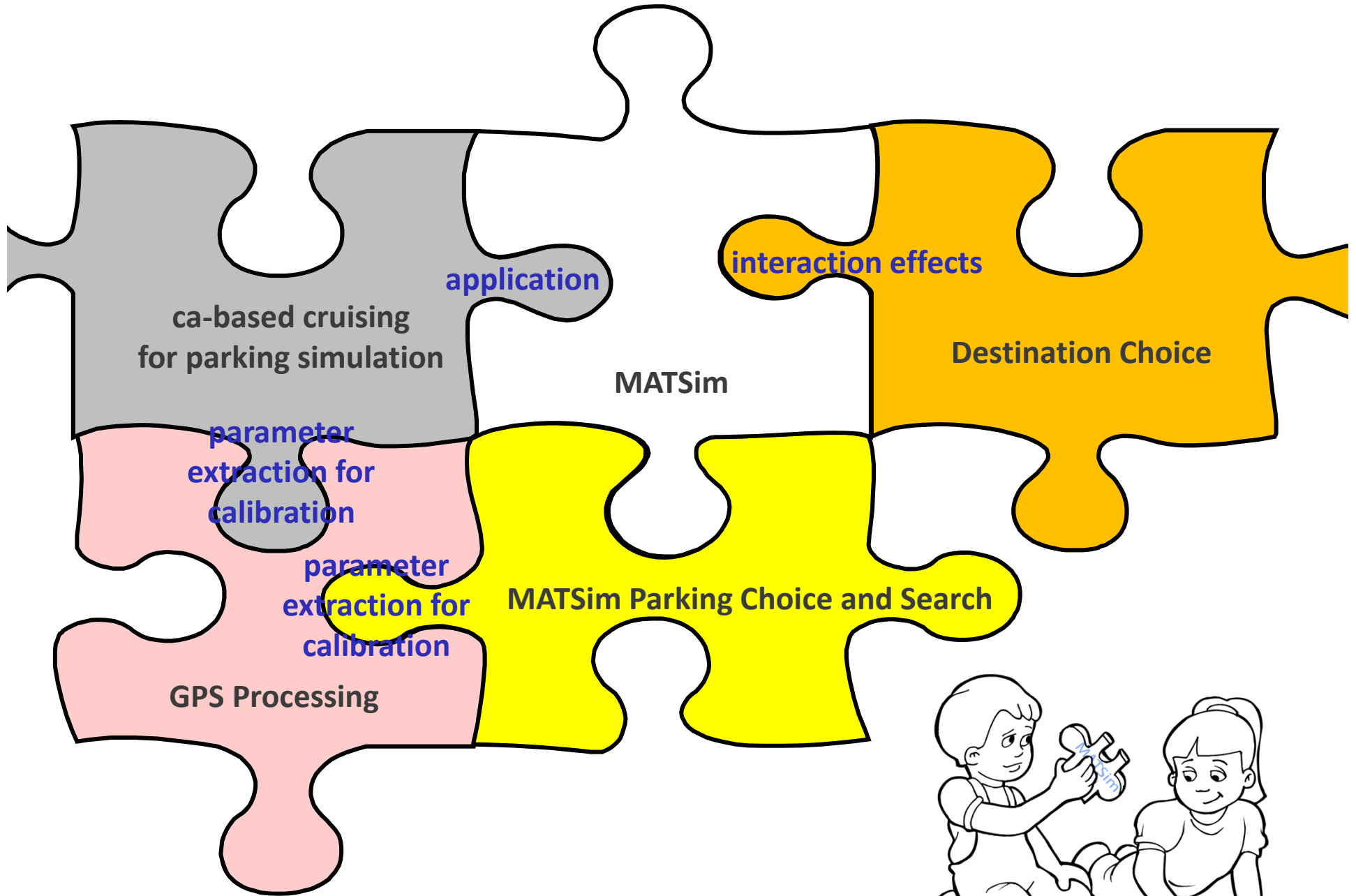
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IVT  
ETH  
Zürich

June 2012

**ETH**

Eidgenössische Technische Hochschule Zürich  
Swiss Federal Institute of Technology Zurich





# Parking Search – A Big Problem or a Phantom?

## Auf Parkplatz-Suche jeden Tag zweimal um die Welt

Verkehrsstudie in Schwabing: Jedes zweite Auto „auf der Pirsch“

Es gibt Stadtviertel, da ist die Hälfte der Autos nur unterwegs auf Parkplatze. Ein solch klassischer Brennpunkt ist Schwabing. Dort drehen so viele Autos die Runde um den Block, daß Tag für Tag insgesamt eine Strecke von 80.000 Kilome-



bin dre ver chü Lär Stu die Lär ten

TagesAnzeiger

ZÜRICH SCHWEIZ AUSLAND WIRTSCHAFT BÖ

Stadt Zürich Winterthur Region Verkehr Bildstreck

## Parkplatzstreit: Rechtsexperten entlasten Zürcher Stadtrat

Aktualisiert am 23.11.2011 26 Kommentare

Geschäftsleute der Zürcher Innenstadt warfen dem Stadtrat vor, Dokumente zum «historischen Kompromiss» gefälscht zu haben. Einem Untersuchungsbericht ist der Vorwurf haltlos.



## Parkplatznot ist Schikane

Der Verein „Mobil in München“ kritisiert die rot-grüne Verkehrspolitik

„Die politische Zielsetzung einer ‚autofreien Innenstadt‘ muß aus den Programmen gestrichen werden.“ Das fordert der Verein „Mobil in München“. Vorsitzender Michael Haberland bemängelt die akute Parkplatznot und immer mehr Beschränkungen im Verkehr.

„Wenn Autos in einigen Jahren sehr viel leiser und schadstoffarmer sind, werden die Leute sagen: Warum haben die Idioten in den 90er Jahren die Parkplätze weg-gemacht?“ CSU-Stadtrat Wolfgang Wiehle, zweiter Vorsitzender des Vereins, schießt damit scharf gegen

die rot-grüne Stadtregierung allgemein – und ganz gezielt gegen Stadtbaurätin Christiane Thalgott, die mit ihrem gerade vorgestellten neuen Stadtentwicklungsplan bei „Mobil in München“ auf ein völliges Unverständnis stößt.

So soll die nur in München und Nürnberg existierende „Stellplatzbeschränkung“ über große Teile der Stadt ausgeweitet werden. Also: Ersatzlose Entfernung von Parkplätzen. Dasselbe aber der falsche Weg, so Wiehle. Sein Forderungskatalog sieht deshalb an erster Stelle vor, die Satzung („schon das Wort ist ein Ungeheum“) abzuschaffen. Nur dann könnten folgende Maßnahmen für eine seiner Meinung nach bürgerfreundliche Park-platzpolitik greifen:

- Schaffung von Anwohnergaragen.
- Bau von modernen Parkhäusern, die Autos nach einer Art Regalsystem unterstellen (so finden mehr Autos Platz, und sie sind sicher vor Diebstahl).
- Abschaffung von Park-lizenzbereichen.
- Duldung von Schräg- und Senkrechtparkern, sofern es die Breite der Gehwege zuläßt.
- mehr Park & Ride-Plätze.

Eine „schikanöse“ Verkehrspolitik, in der die Münchner gezwungen würden, auf öffentliche Verkehrsmittel umzusteigen, sei



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# MÜNCHEN

München Medizin: **Romans Kampf um ein neues Herz** Seite 22

## Die ewige Parkplatz-Sucherei

Täglich 80 000 km um den Block allein in Schwabing

ders ausgedrückt. In 24 Stunden finden in dem Stadtteil rund 80 000 Kilometer „Park-suchverkehr“ statt. Das ergab eine Studie der BMW Verkehrsforschung, die der Verein „Mobil in München“ am Freitag vorstellte.

Parksuchverkehr – ein häßlicher Ausdruck und ein stetes Ärgernis. Wer nach Feierabend eine halbe Stunde um den Block kurvt, um die Blechkiste abstellen zu können, wer seinen Zahnarzttermin verpasst, weil partout kein Parkplatz zu finden war, gehört zu den Leidtragenden.

Und er gehört einer riesengroßen Gemeinschaft an. Denn 44 Prozent aller Autofahrten etwa in Schwabing, so ergab die BMW-Studie, dienen nur dem einen Zweck: Parkplatzeuche.

Fast jedes zweite Auto würde also im Idealfall schlagartig von den Straßen verschwinden, wenn es genügend Parkplätze gäbe.

In mehreren Schwabinger Straßen recherchierte BMW durch schlechtes Hinterherfahren bei fast 1500 Autos, ob und wie lange nach einem Abstellplatz gesucht wurde. Dabei erreichte die Viktor-Scheffel-Strasse einen unheimlichen Spitzenplatz: Hier fahren nur acht Prozent aller Autofahrer freiwillig rein – 92 Prozent tun's auf der Suche nach einer Lücke.

Abhilfe tut Not, meint „Mobil in München“-Vorsitzender Michael Haberland. Er fordert unter anderem die konsequente Umsetzung der Planungen für Anwohnergaragen, speziell im arg belasteten Schwabing. Außerdem setzt sich der Mobilitätsverein für ein Parkleitsystem ein, das unnötige Rummelfahren bei der Parkplatzeuche in der Innenstadt nahezu vollständig abstellen soll.

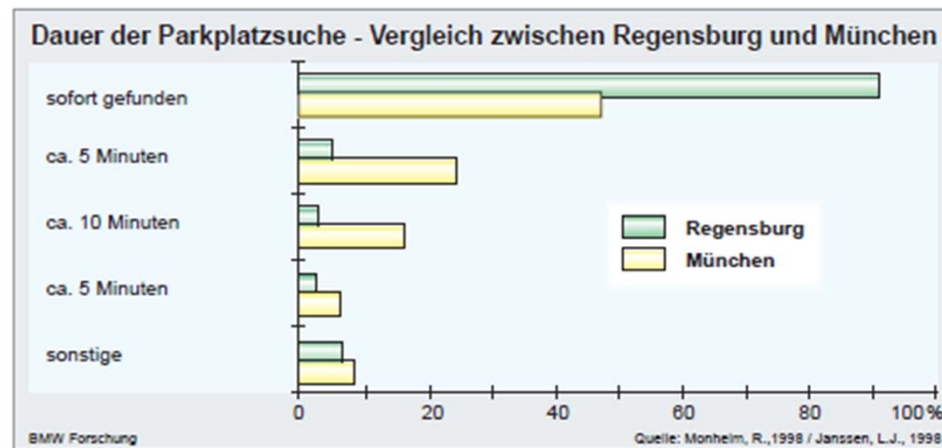
Mit dieser Forderung läuft Haberland bei OB Christian Ude und seinem Herausforderer Albert Wolf (CSU) offene Türen ein: Beide wollen sich für ein solches Parkleitsystem einsetzen.

# Studies

D. C. Shoup (2006) Cruising for parking

“[...] studies of cruising in congested downtowns have found that it took between 3.5 and 14 min to find a curb space, and that between 8 and 74 percent of the traffic was cruising for parking.”

München / Regensburg

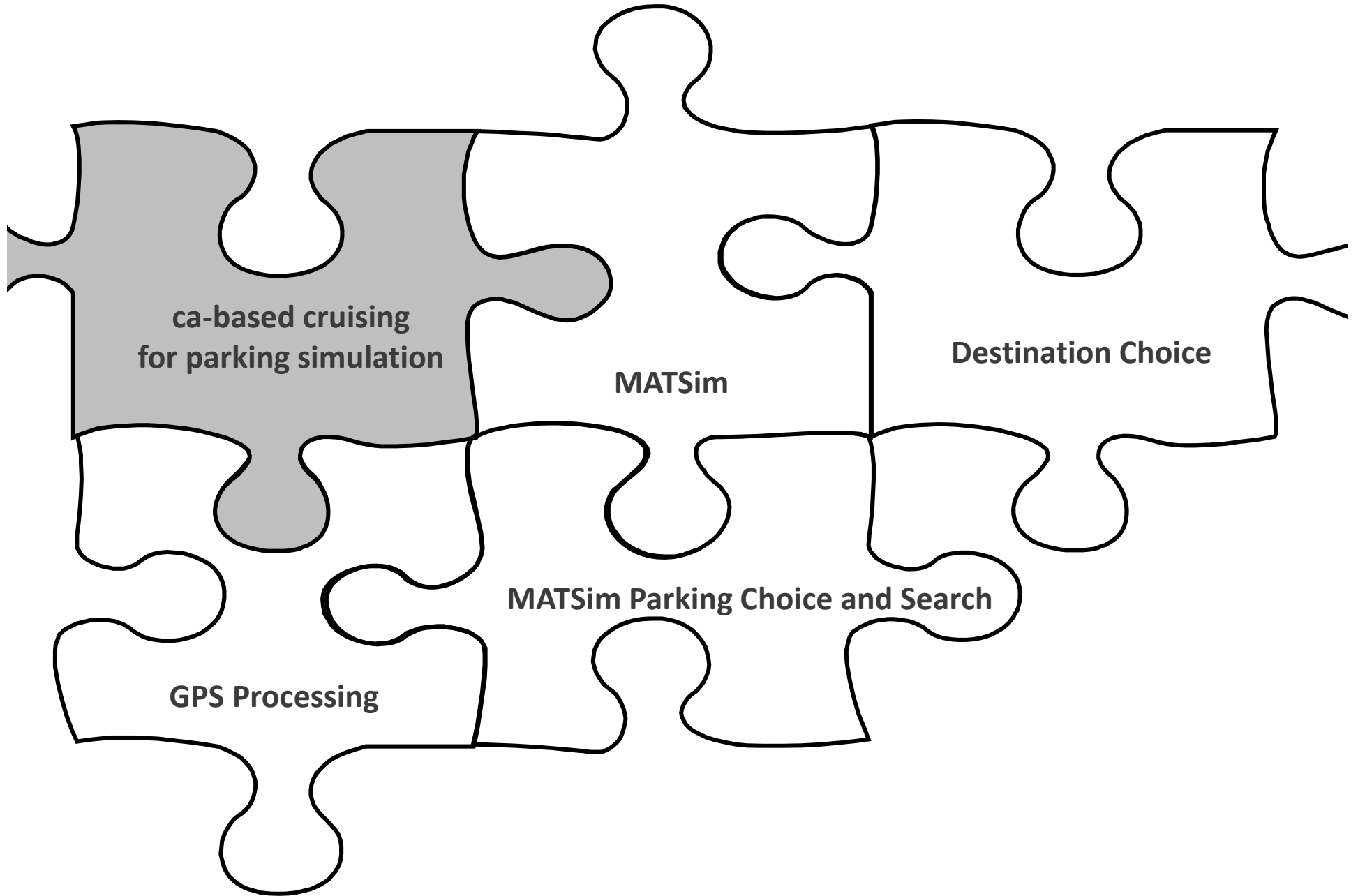


Frankfurt (1992- 1993)

average search times on Saturdays 5.5 – 10 minutes (decreasing after introduction of PGI)

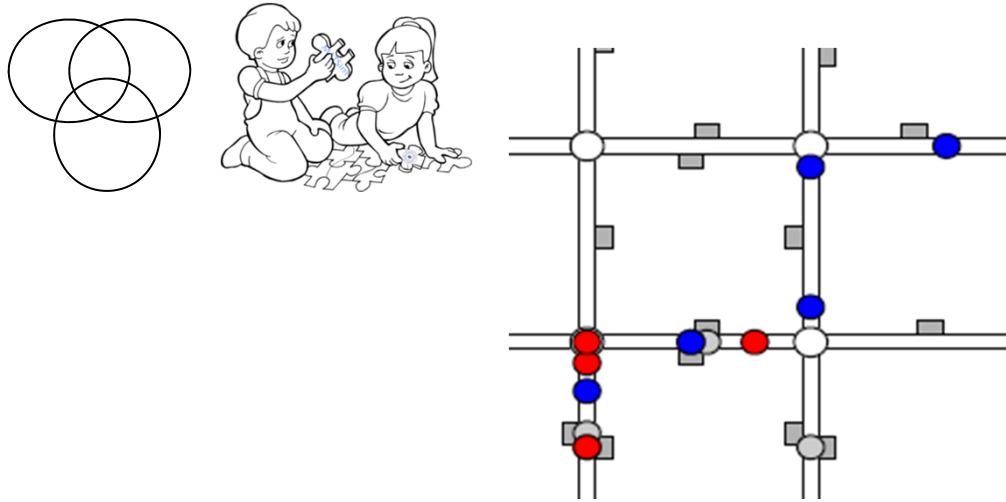
Zürich (2010)

parking occupancy inner city (Saturday) ~ 97 %





# LaHowara & Commander Spock: Lecture MSSSM



## Exploring en-route parking type and parking-search route choice: decision making framework and survey design

Sigal Kaplan<sup>1</sup>, Shlomo Bekhor<sup>2</sup>

Kaplan and Bekhor (2011): very similar approach,  
GPS study

→ personal (controversial) communication started

→ meeting Carlo Prato @ IATBR



# Goal of CA

Implement agent-based cellular automaton cruising-for-parking simulation to generate aggregate models for parking search key measures:

here:  $\tilde{t} = f(\text{supply})$

supply: # parking spaces in area

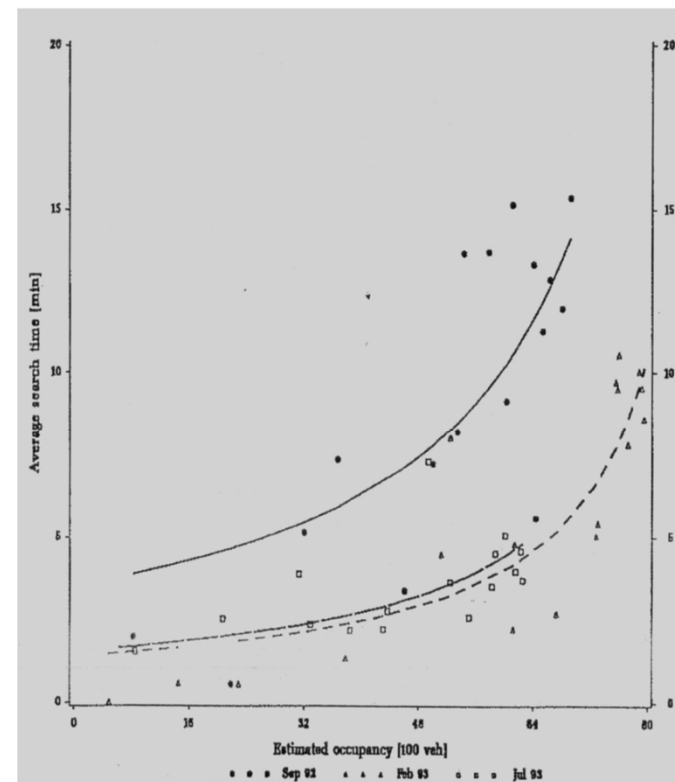
(future: density around destination)

similar to estimated functions

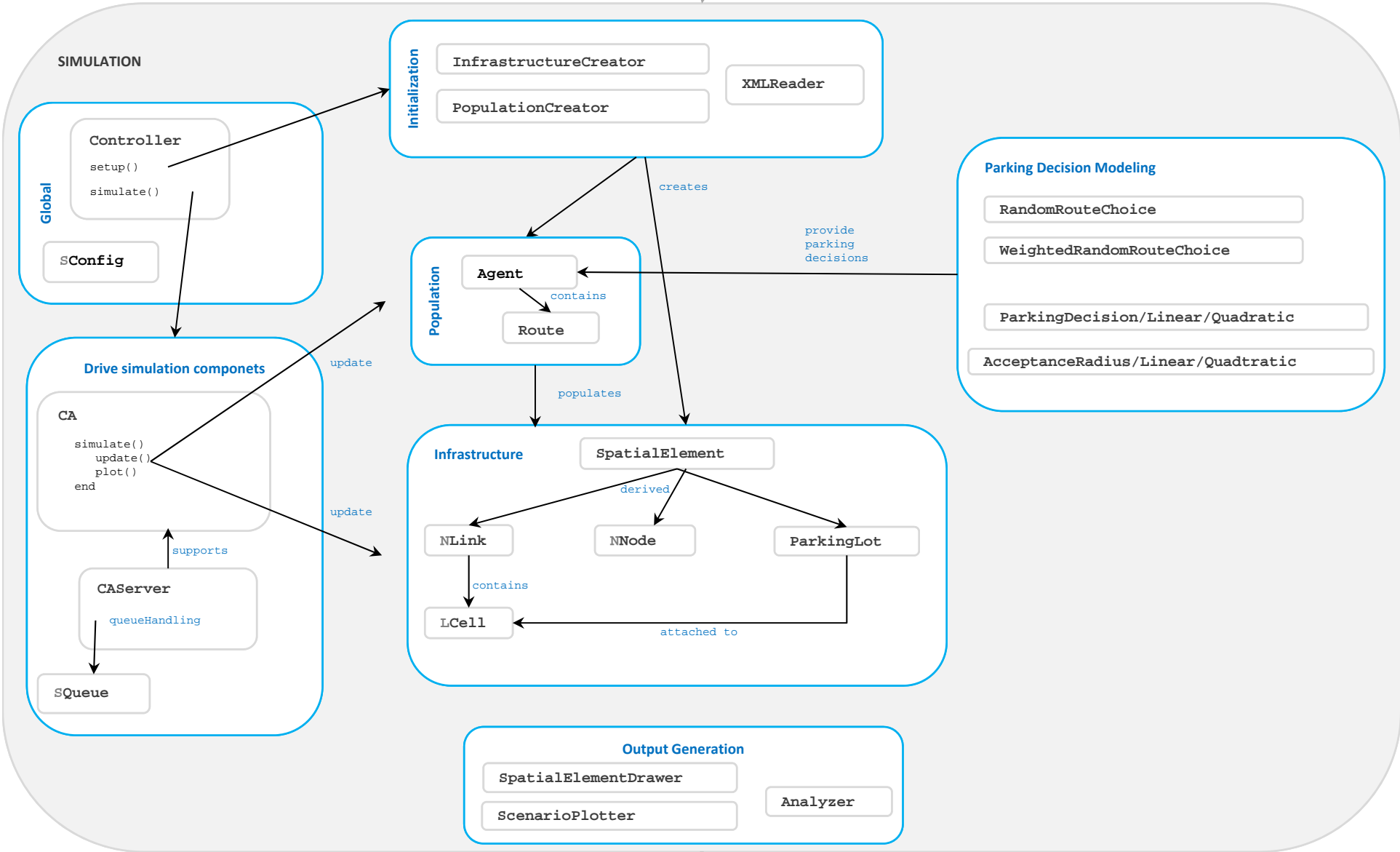
such as ...

Axhausen et al. (1994)

PGI Frankfurt a. M.



# CA Method





## CA Method: Technical but Important Details

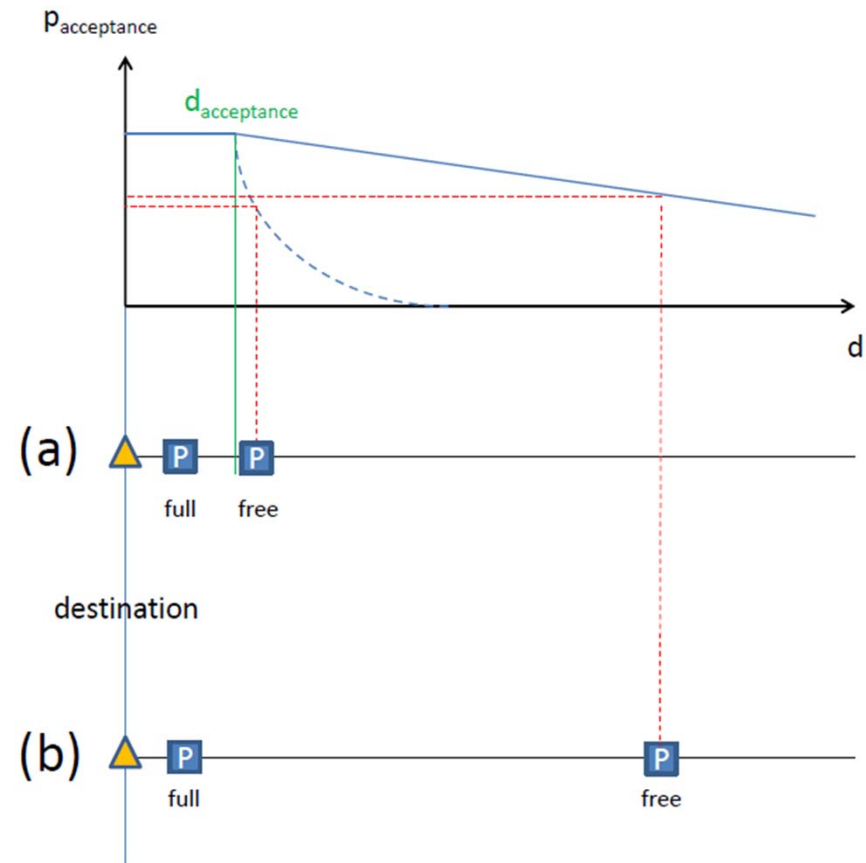
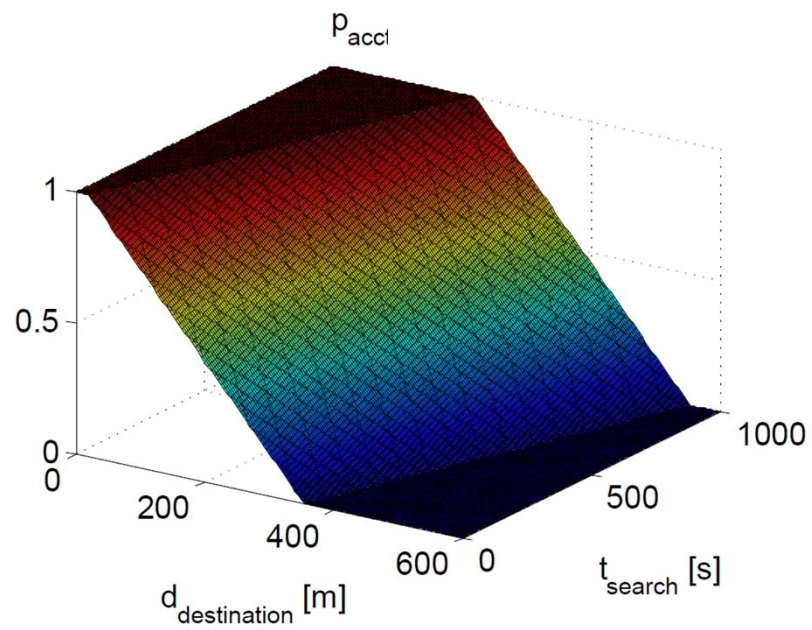
- update process on randomly chosen links, nodes and parking lots as in famous Nagel and Schreckenberg (1992) CA
  - increase, decrease speed dependent on load of link (with  $v_{\max}$  and  $v_{\min}$ )
  - randomize speeds
  - future: parking search speeds
- *CAServer* class for update process:
  - not naively iterating over all agents and infrastructure elements (e.g., cells) but only over occupied ones -> **queues** of agents, links nodes and parking lots
- resolution
  - Queue models – CA – car following models
- jam density used for cell size as in Wu and Brilon (1997)
  - Future: maybe pool cells in free flow conditions

## CA Method: Parking Search Modeling

- parking type choice
  - exogenously, derived from supply (for ZH scenario only)
- search tactic
  - search starting point
  - weighted random walk
    - destination approaching efficiency
    - agent's memory of parking lots with free spaces

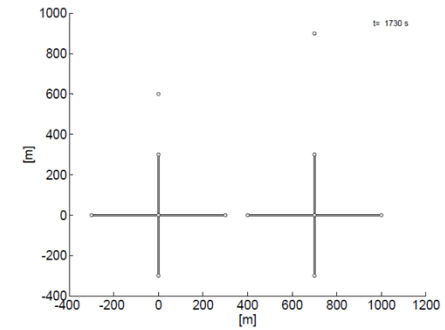
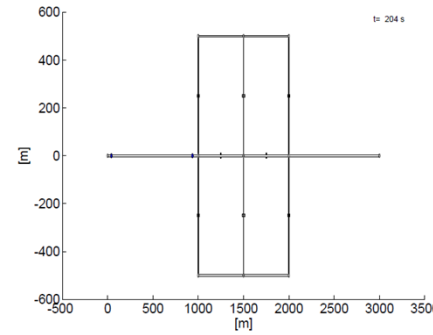
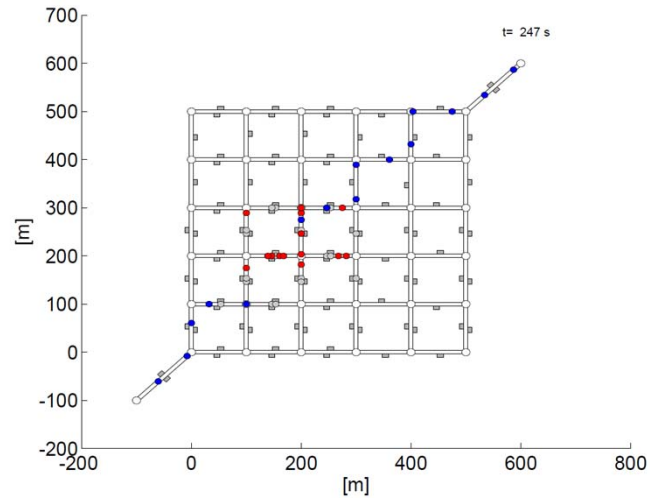
# CA Method: Parking Search Modeling → Calibration

- parking lot choice
  - Acceptance radius

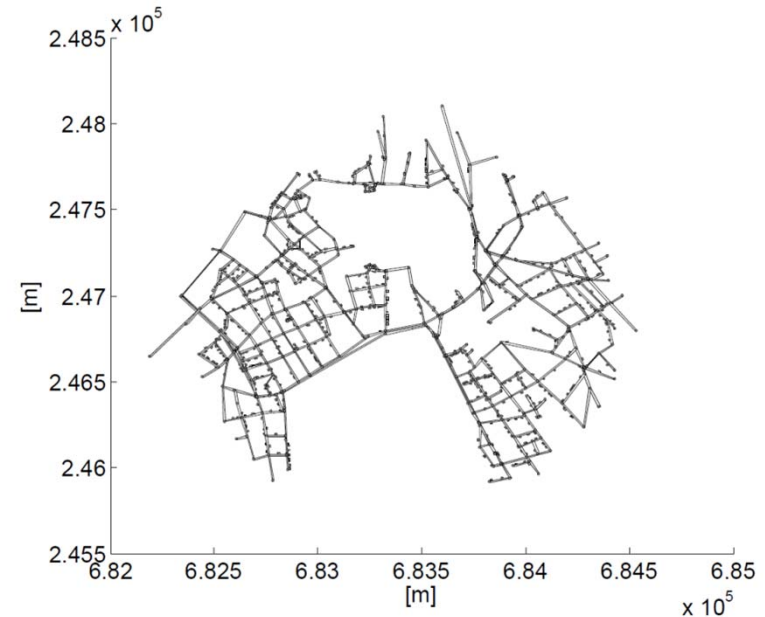


# Results and Scenarios

- 3 small-scale scenarios for development and calibration

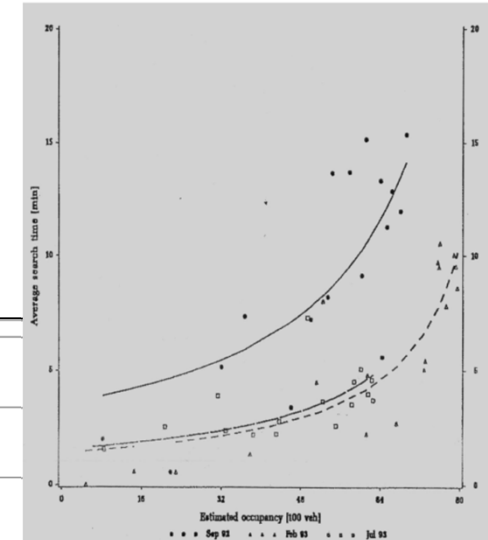
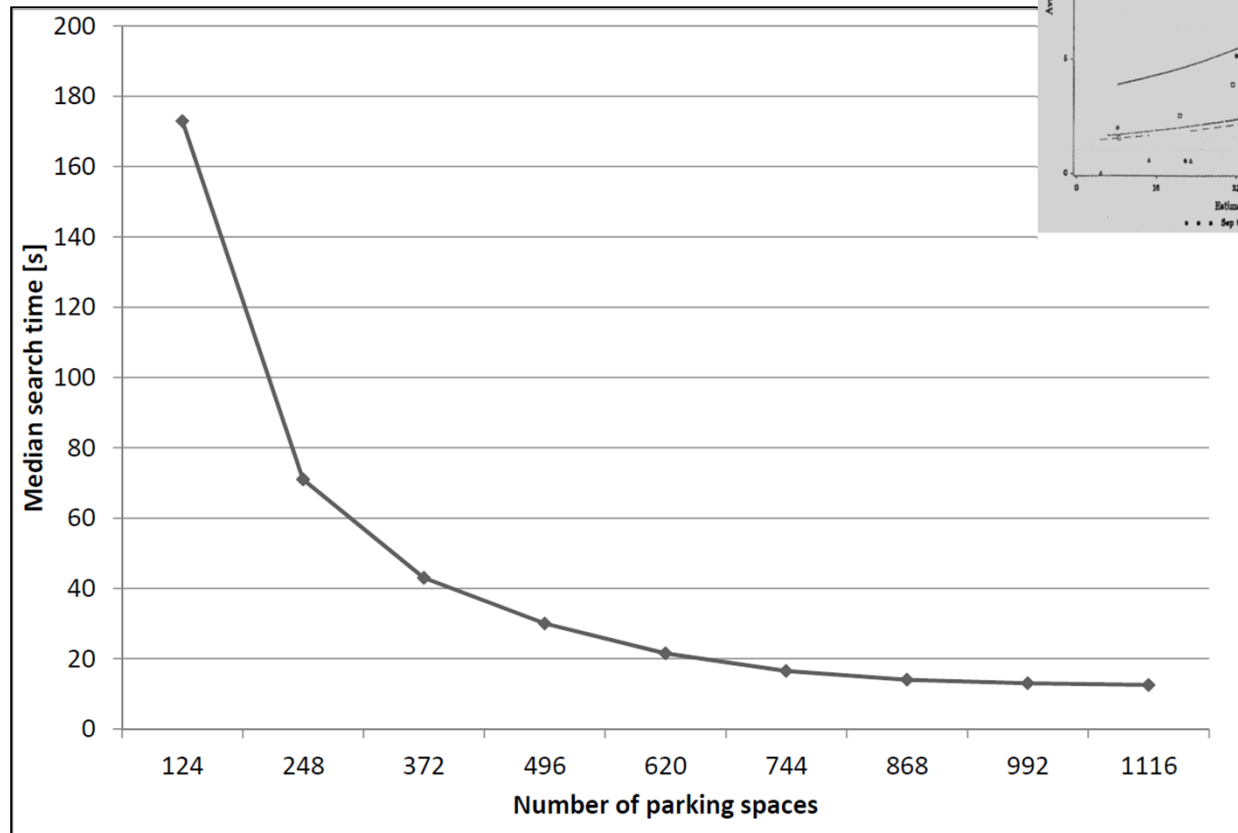


- Zurich Inner-city scenario
  - derived from real-world data (MATSim demand), navigation network
  - ready, but not yet calibrated & speed issues!



# Results: Chessboard Scenario

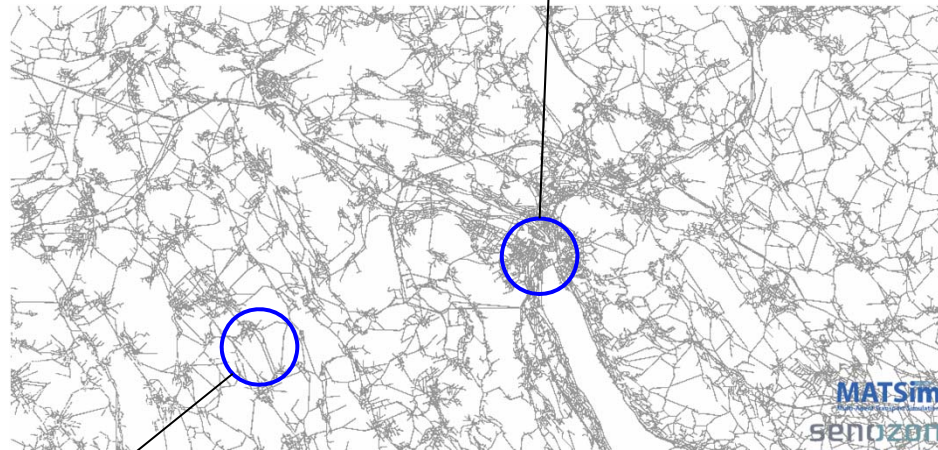
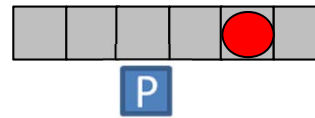
- 100 agents
- 2 origins, 1 destination
- 30 min simulated



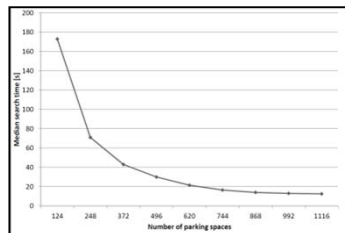


# Future: Application in MATSim: Hybrid Approach

$t_{\text{search}} = \text{simulate with CA}$

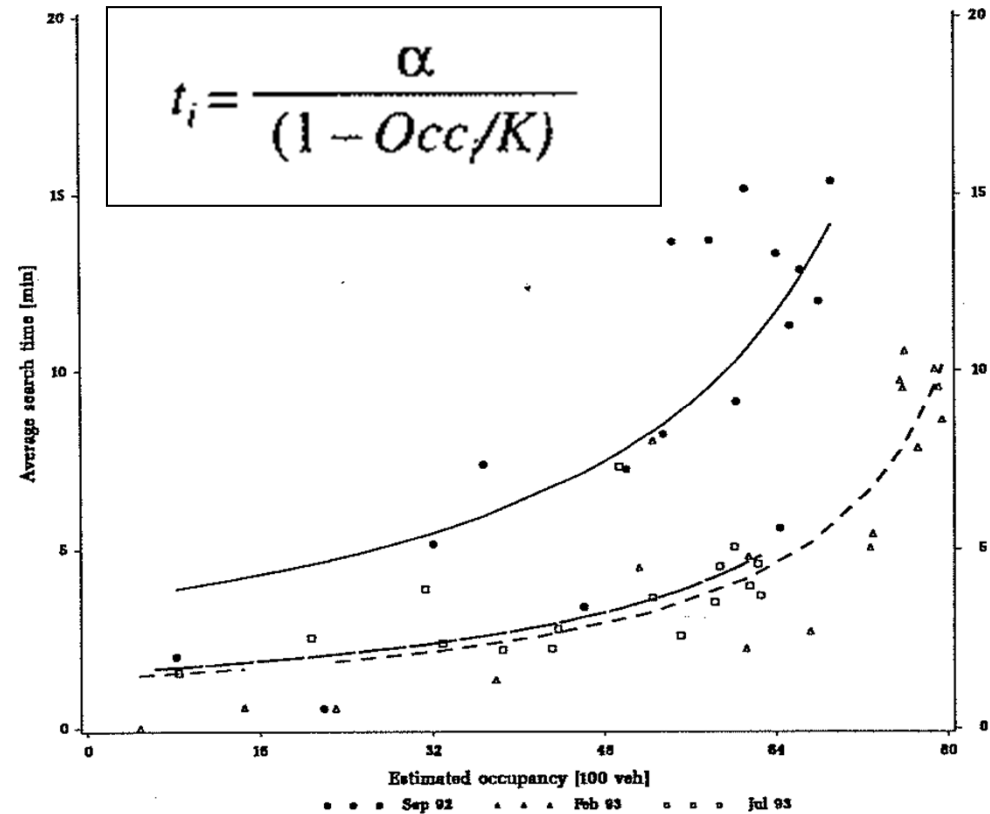
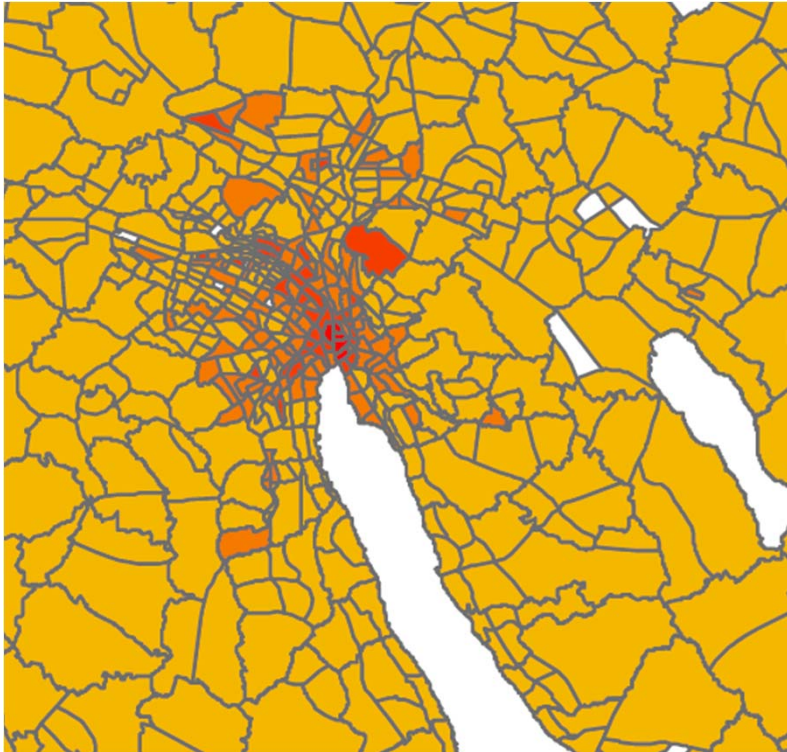


$t_{\text{search}} = \text{sample from aggregate functions}$



really necessary apart from parking studies?  
costs?

# Future: Aggregate Curves Corrections



$\Delta$  ( GPS -  $t_i$  )

→ only rel. diff ( $\Delta\Delta$ ) relevant (st vs. dt)

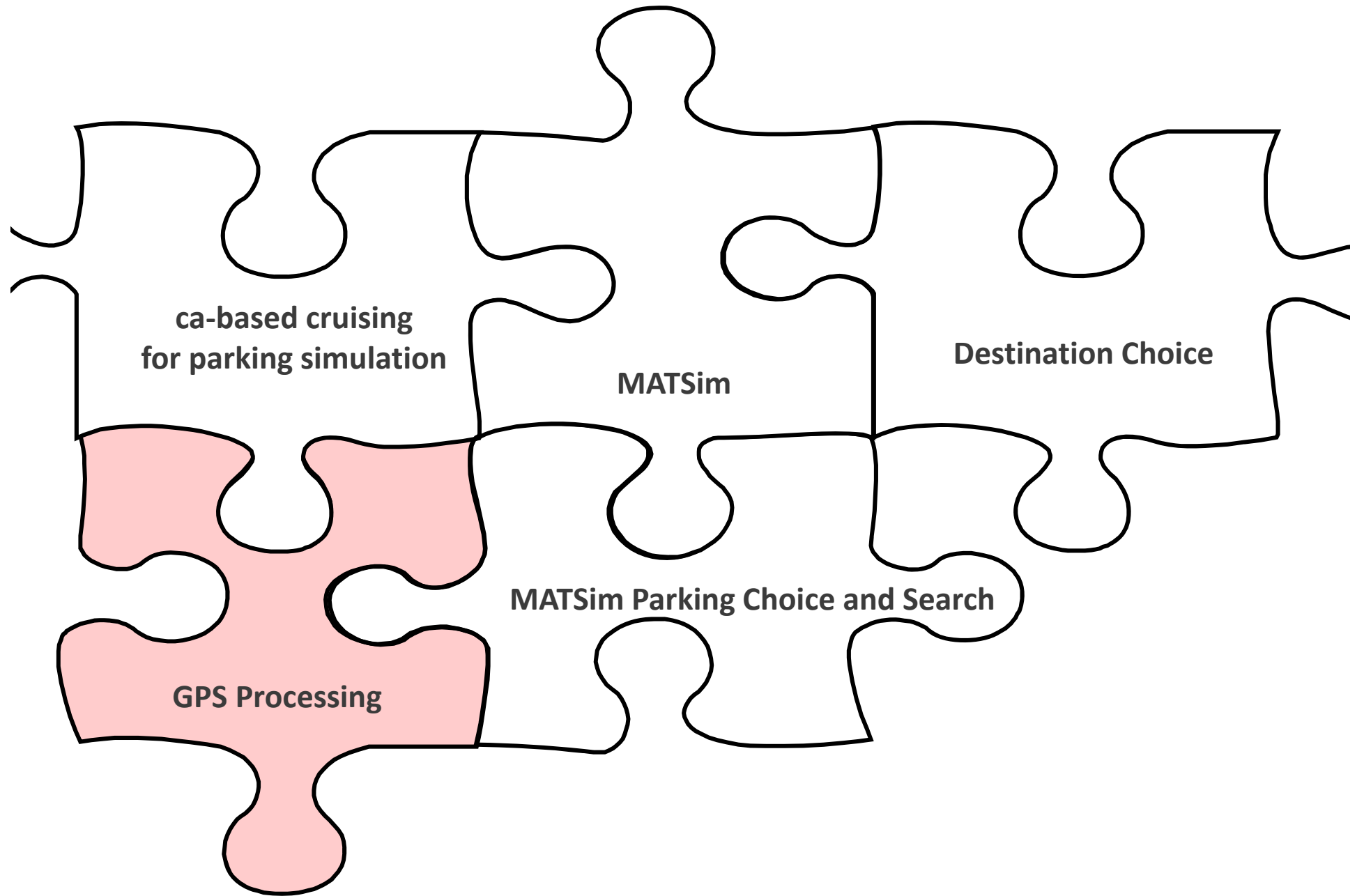
→ plain-colored?

fitting for high Occ

correction factor as  
a follow-up work?

## Discussion: LaHowara & Commander Spock

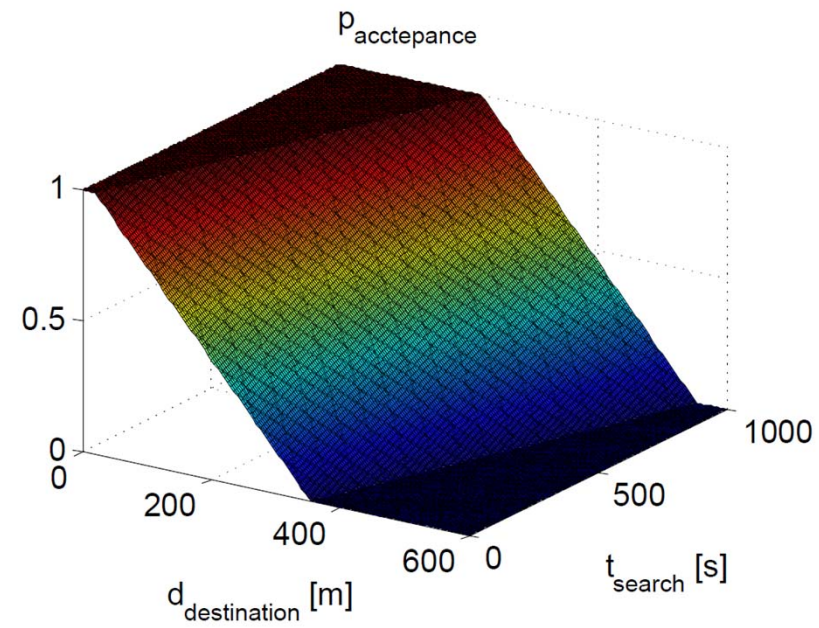
- estimated aggregate functions can be reproduced
- software structure very similar to MATSim -> easy migration
- high simulation costs



# GPS Processing – Extract Parameters

## Calibration

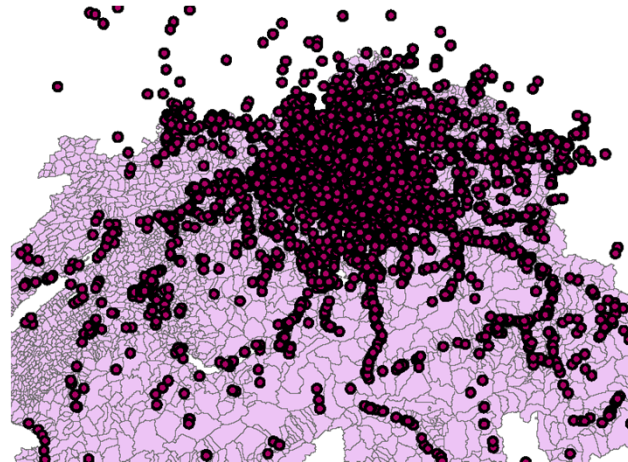
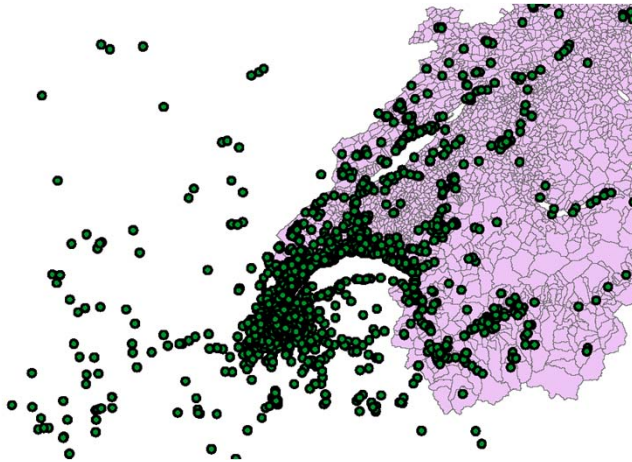
- $p_{\text{acceptance}}$





## GPS Data Available

approx. 32'000 person days from Zurich and Geneva

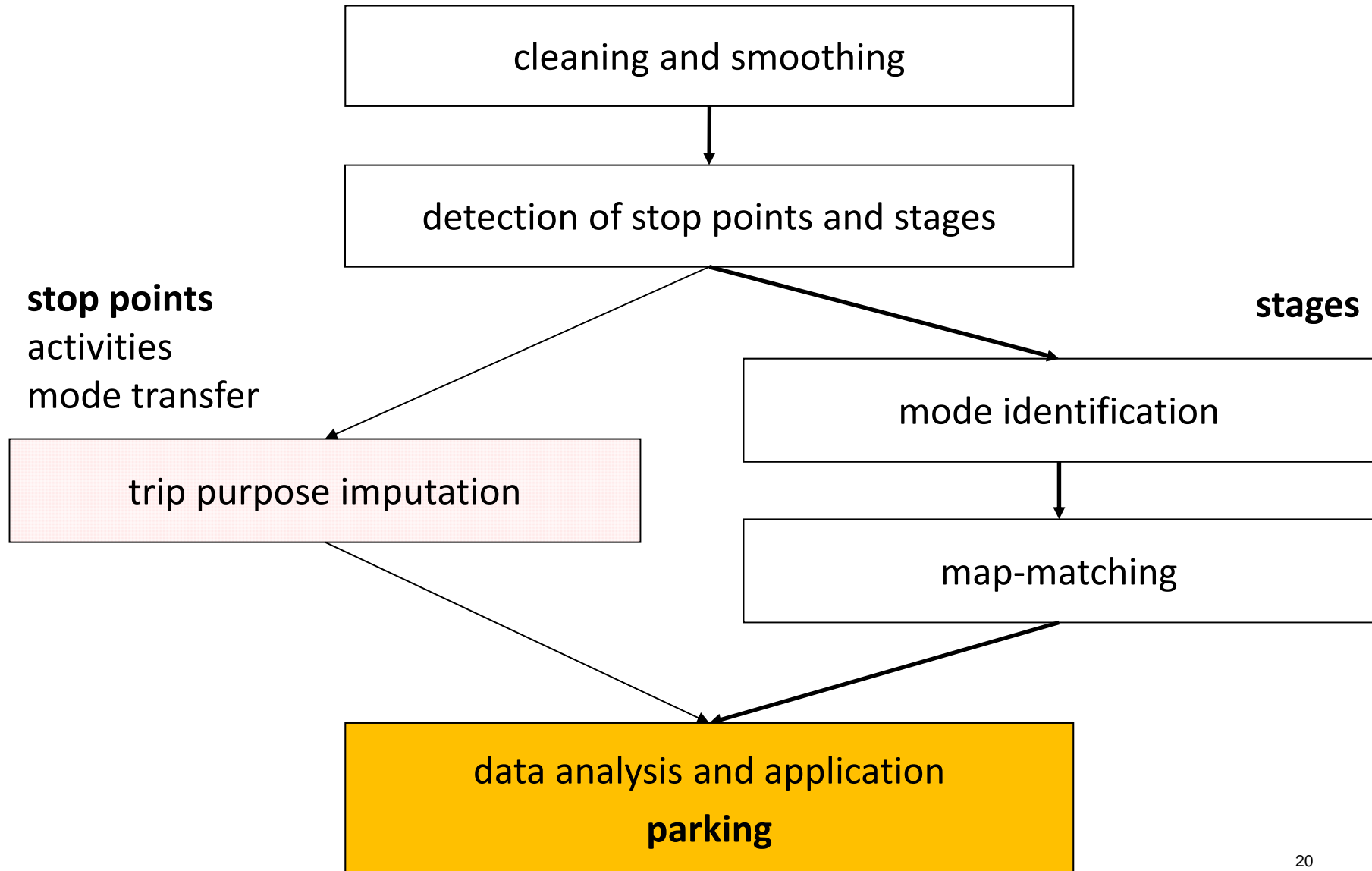


person-based and therefore multi-modal

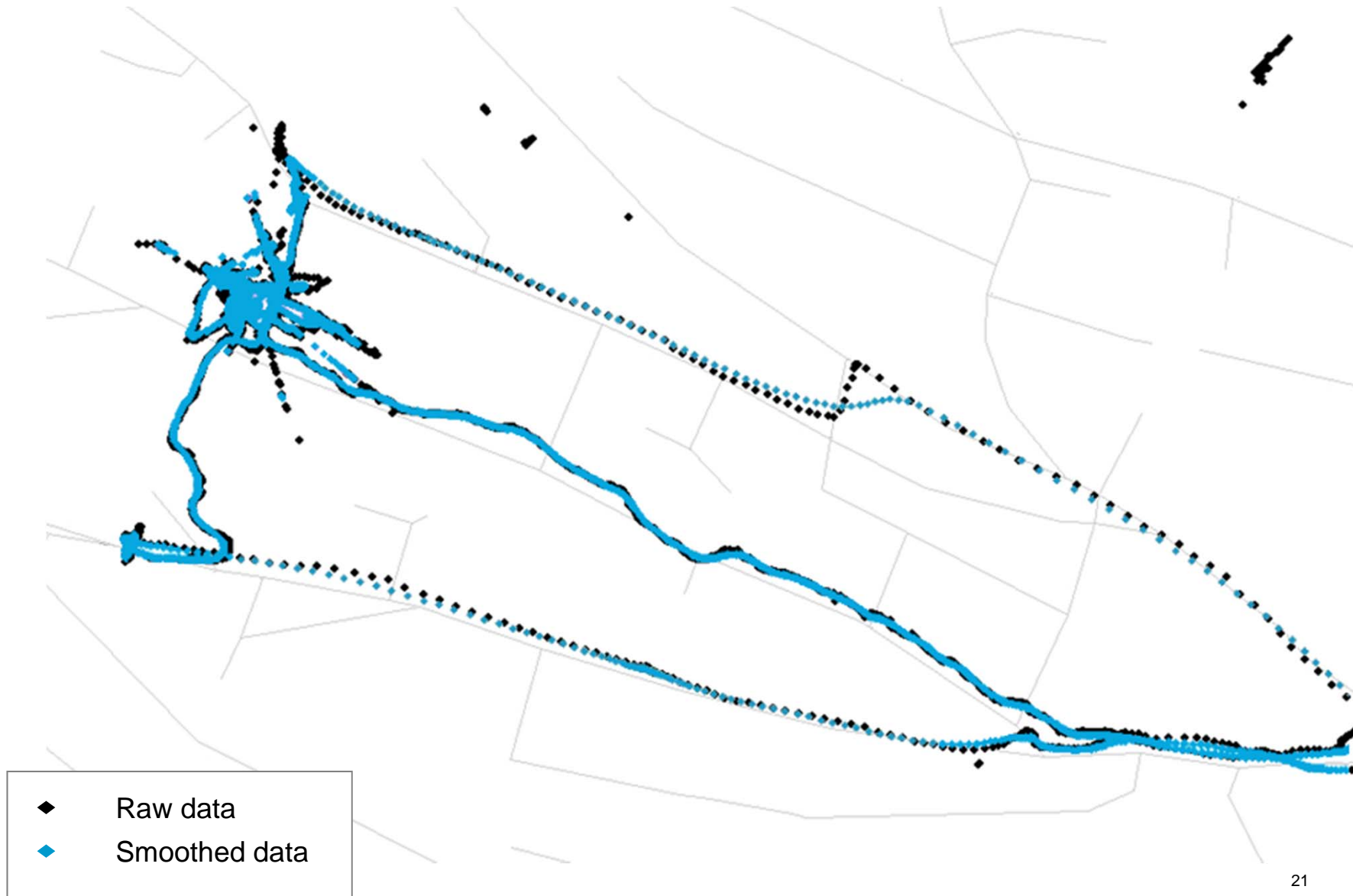
only raw data (x, y, z, timestamp)

no sociodemographics

# Processing of GPS data



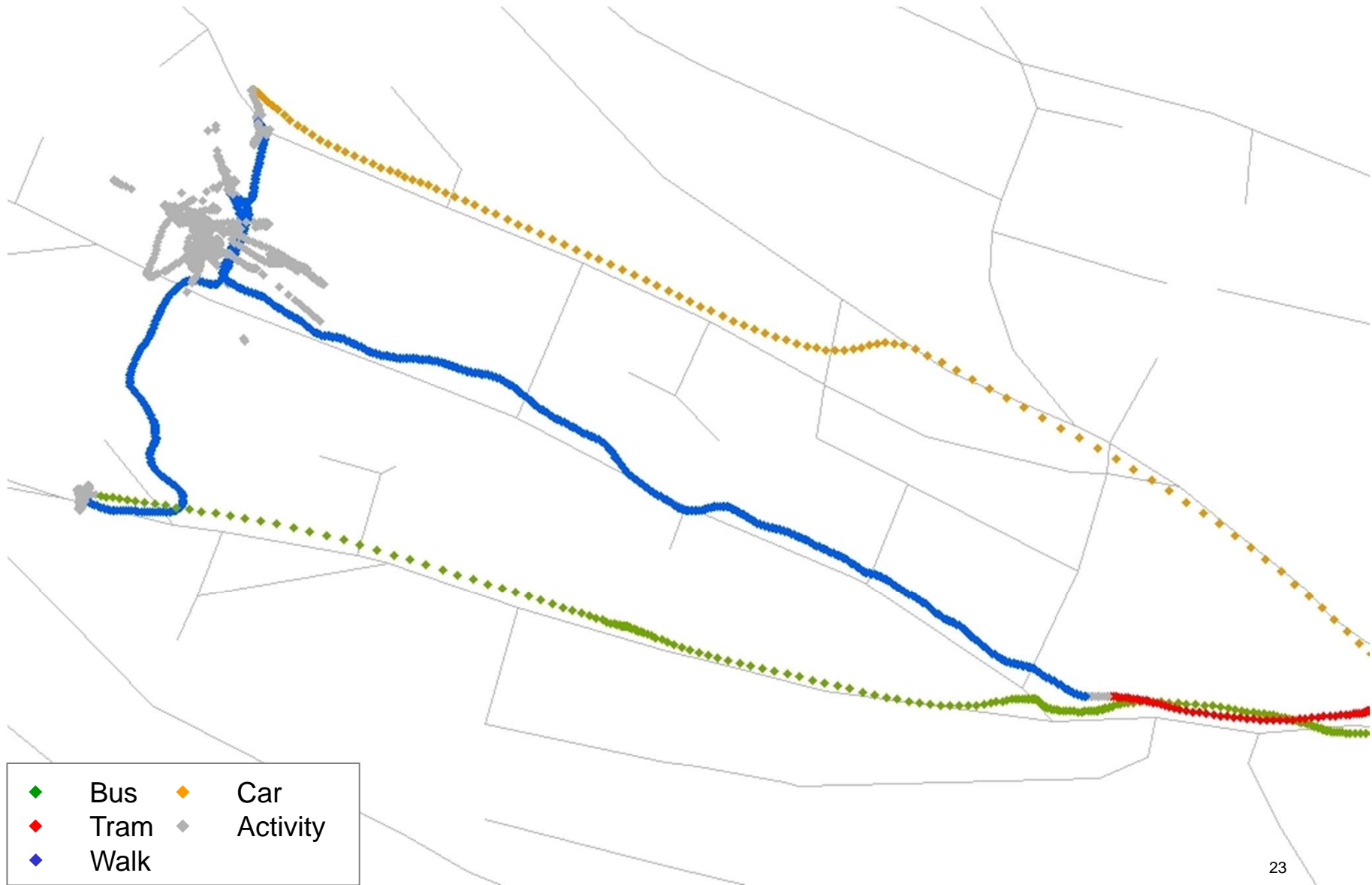
# Data cleaning and smoothing



# Determining stages and activities

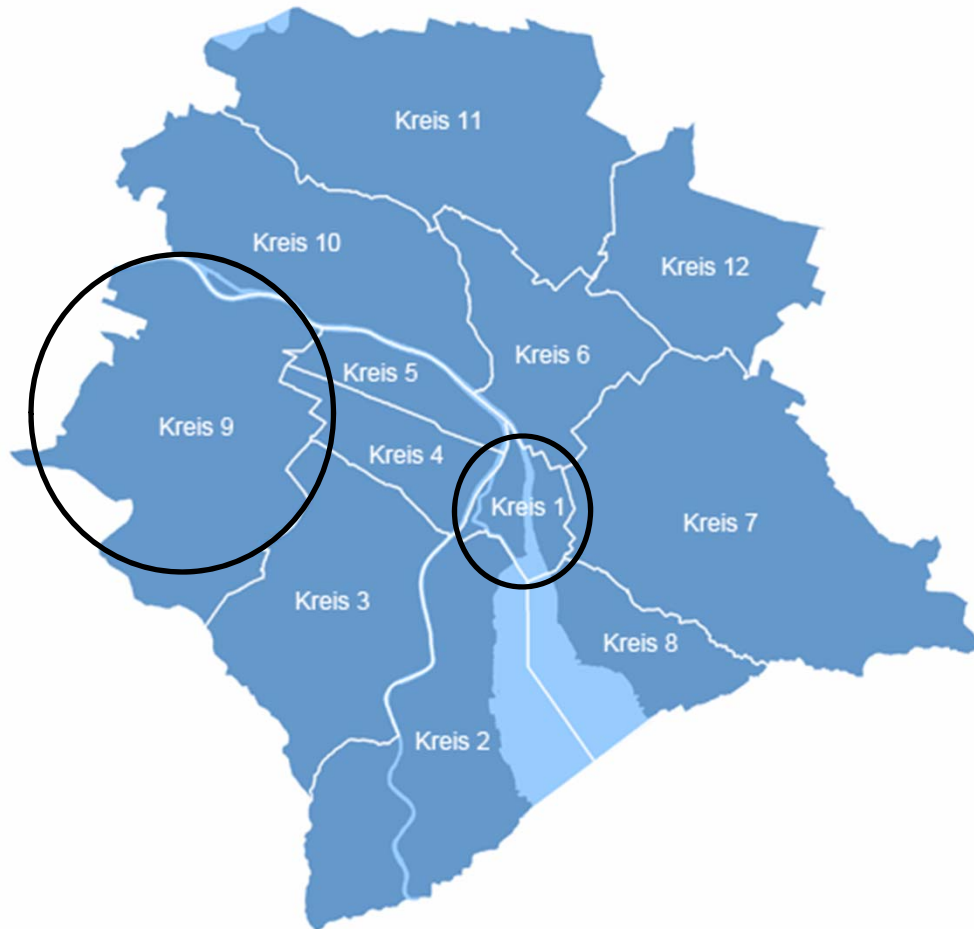


# Mode detection



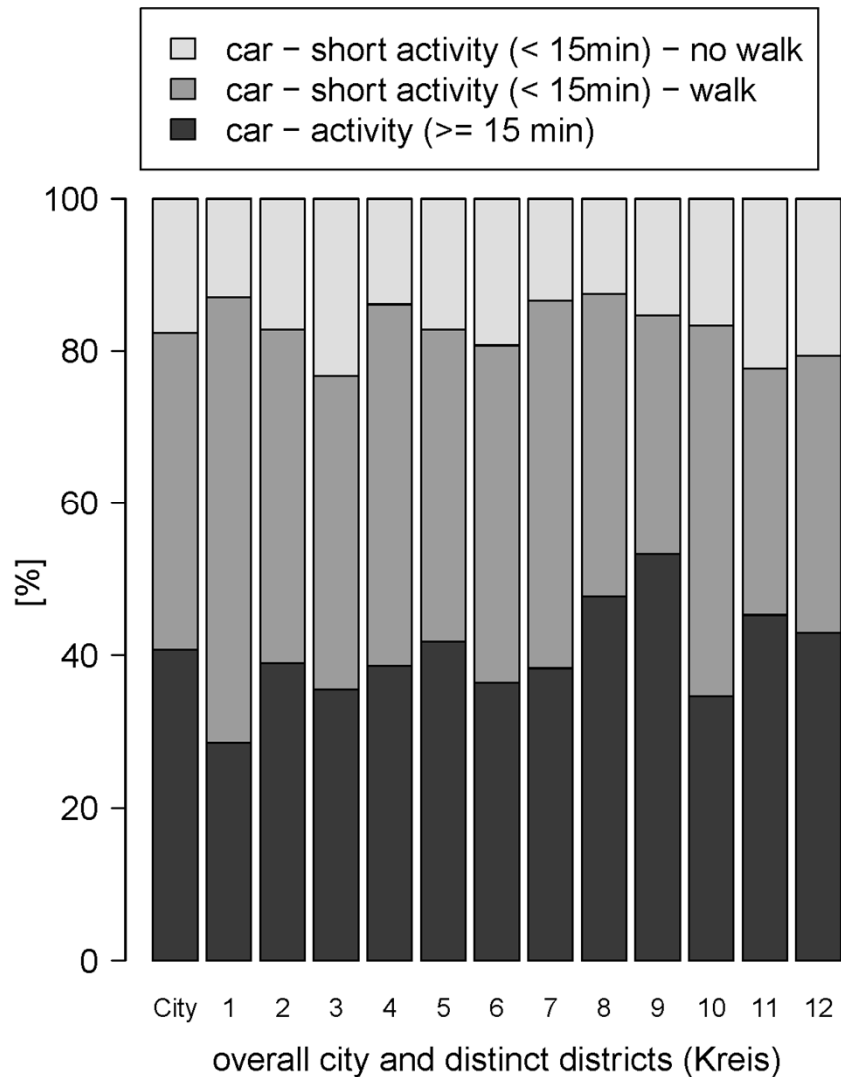


# City of Zurich



District	PP/(Res.+Empl.)
1	0.13
2	0.39
3	0.32
4	0.31
5	0.34
6	0.35
7	0.42
8	0.39
9	0.45
10	0.41
11	0.40
12	0.39
City	0.36

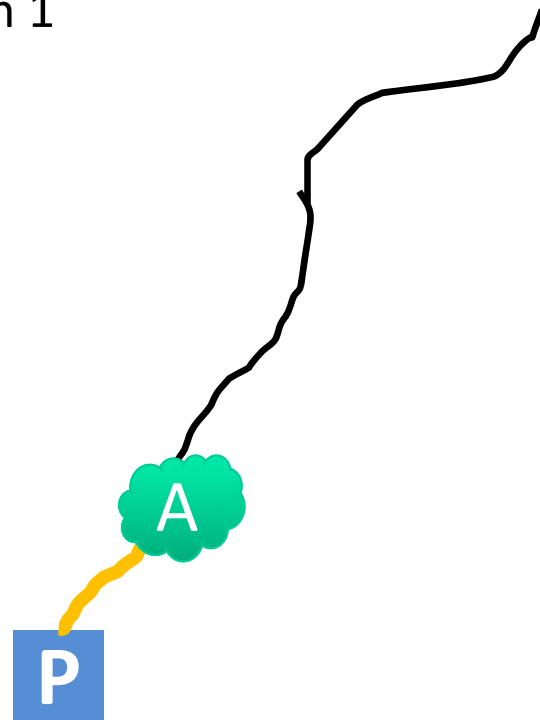
# City of Zurich – Analysis per District



District	Cases
1	294
2	372
3	442
4	368
5	321
6	239
7	269
8	176
9	458
10	312
11	665
12	170
City	4086

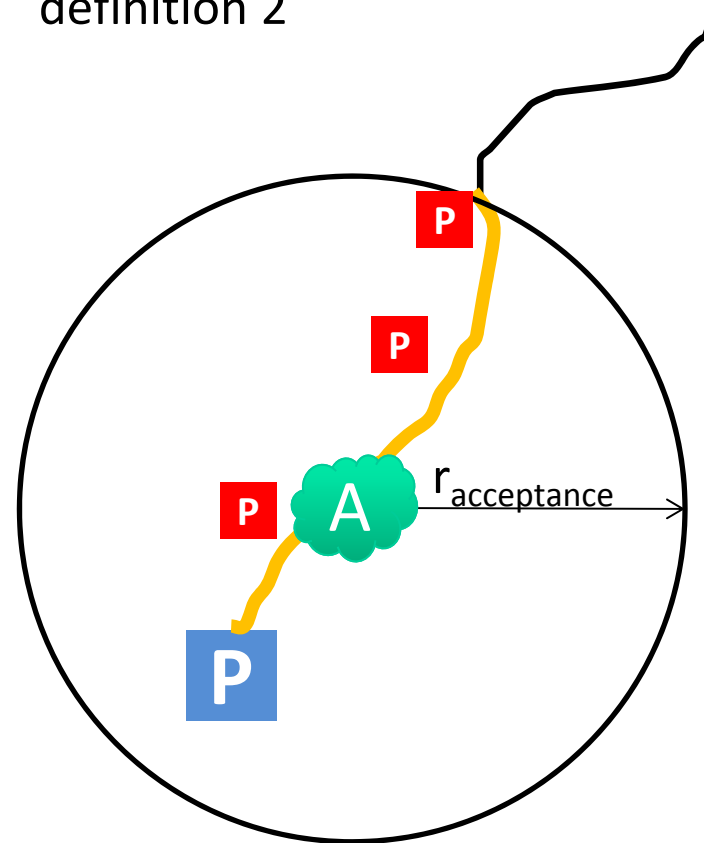
# Parking Search

definition 1



problem: search path does not have to cross the activity.

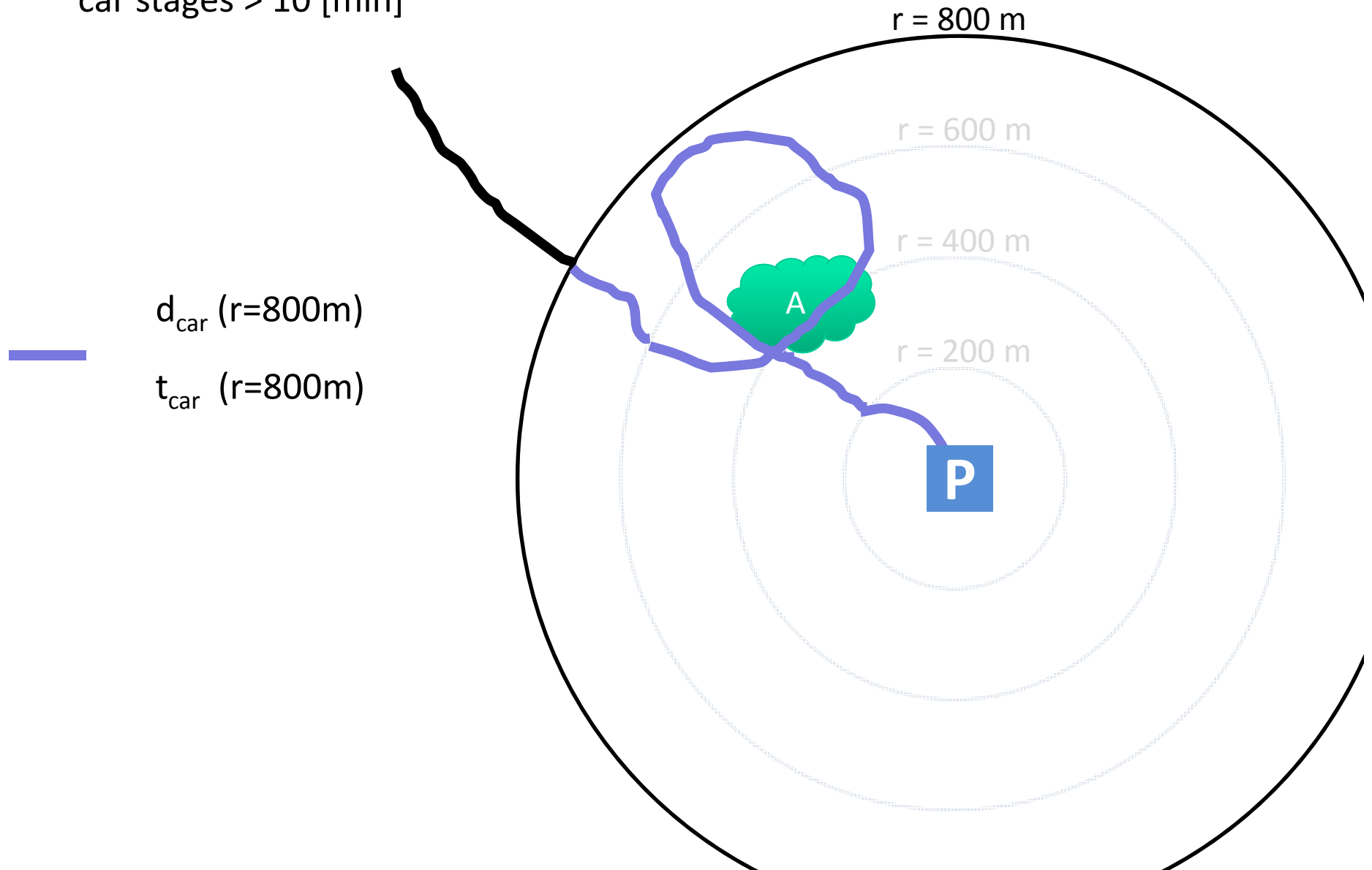
definition 2



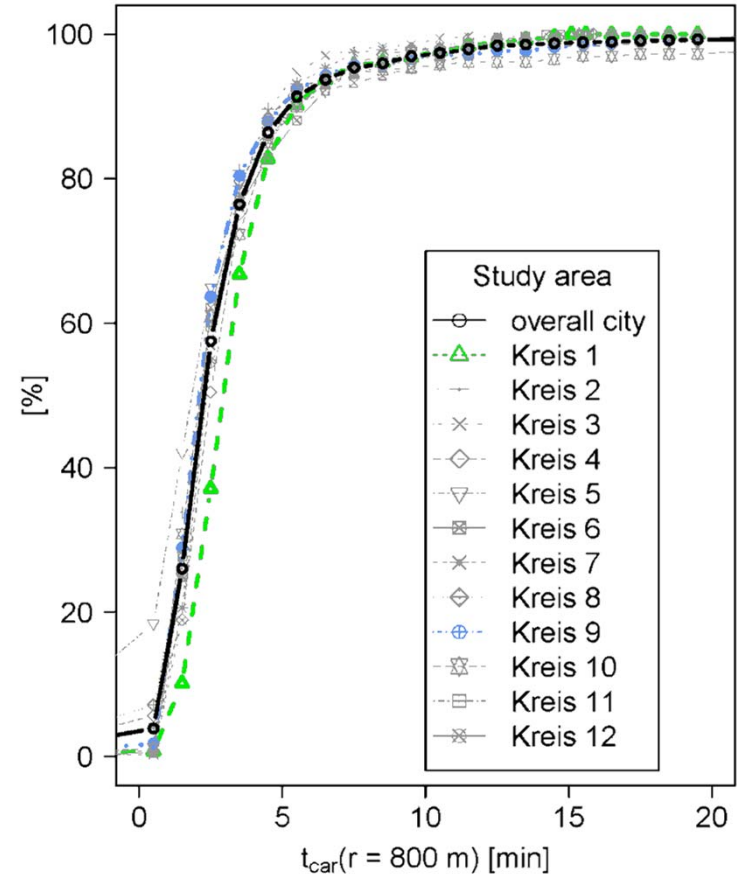
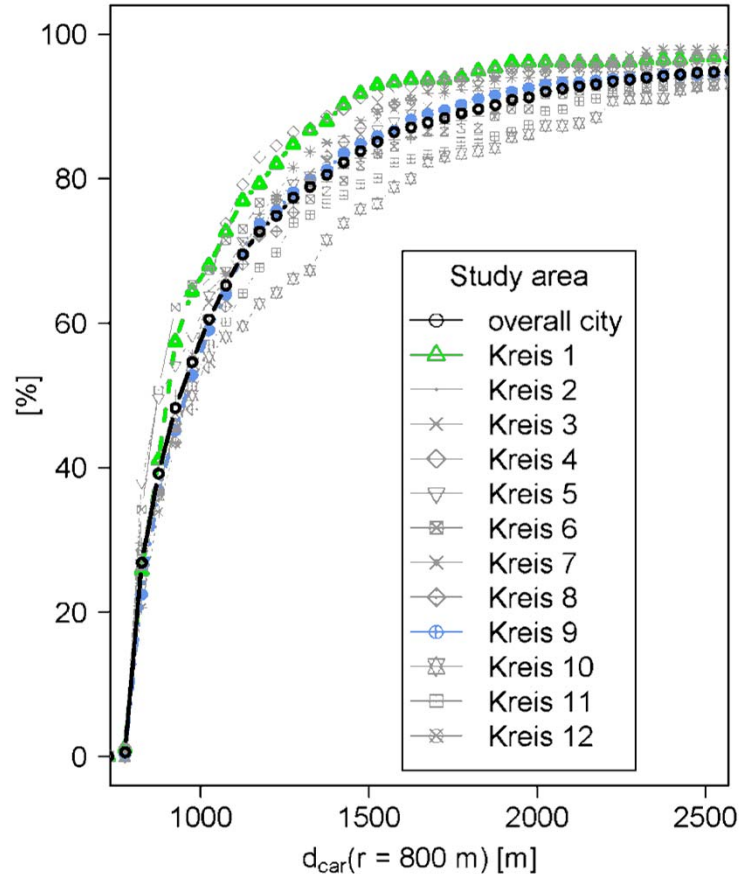
problem:  $r_{\text{acceptance}}$  is individual and situation dependent.

# Car Stage Characteristics

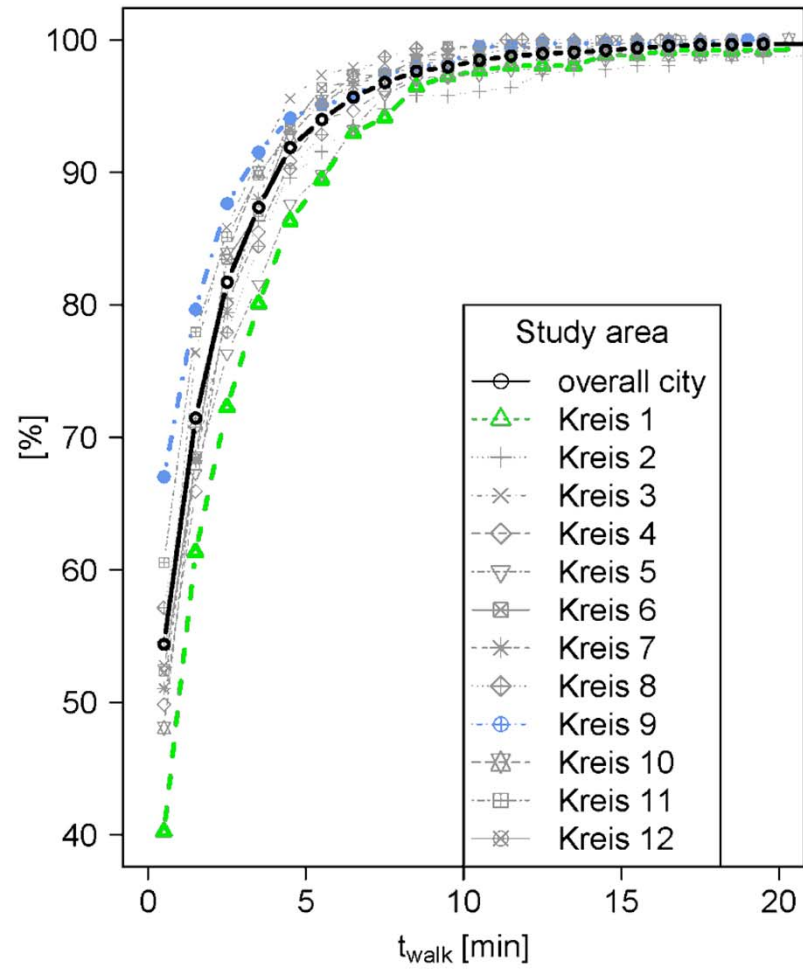
car stages > 10 [min]



# Distance and Time Within 800 m Radius Around Parking



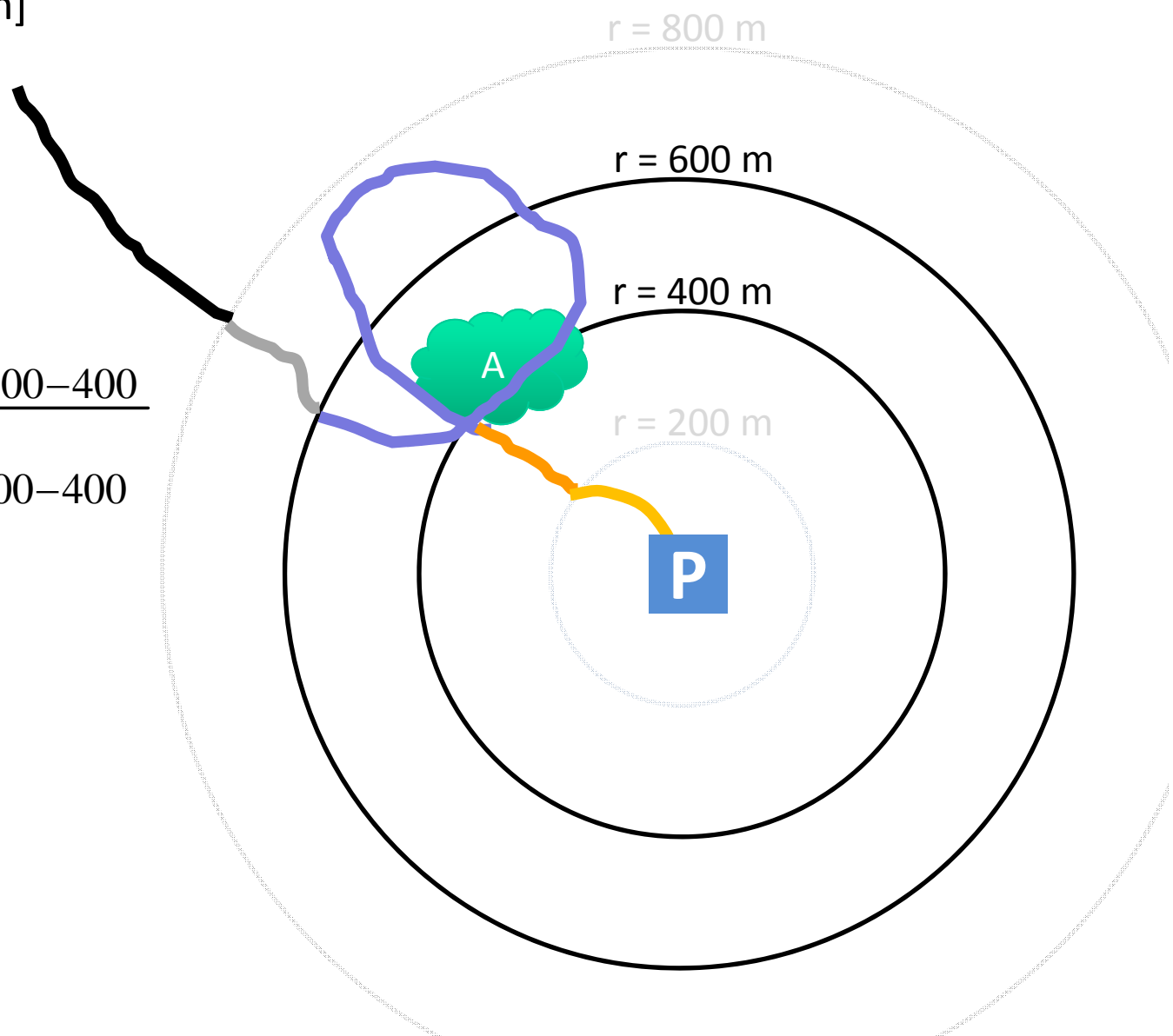
# Walk Times



# Car Stage Characteristics

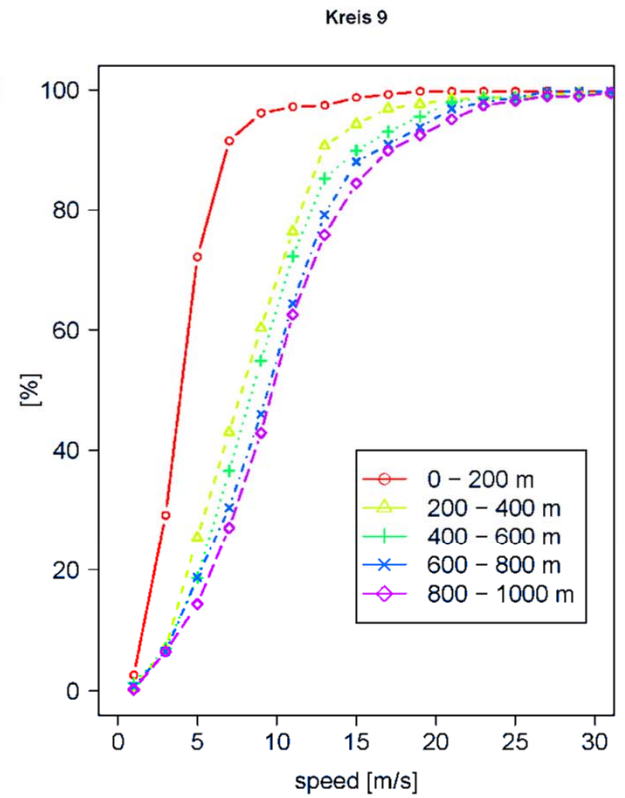
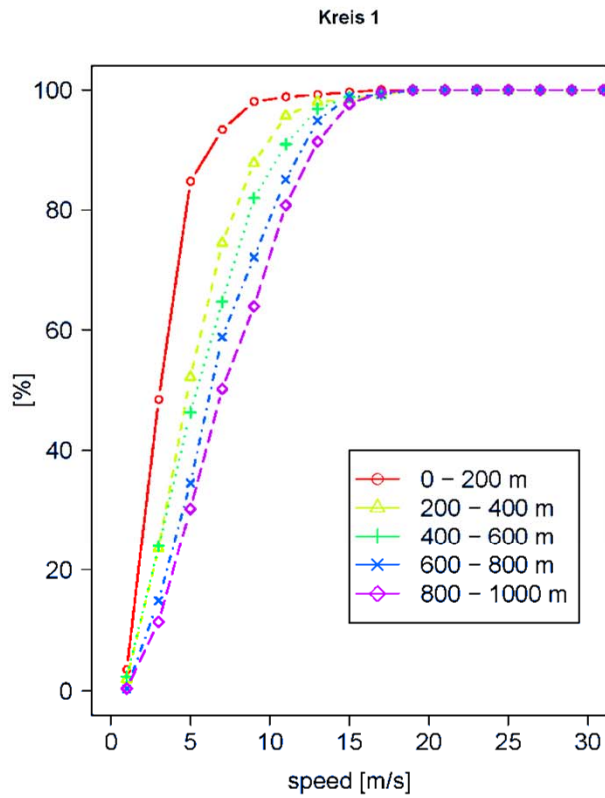
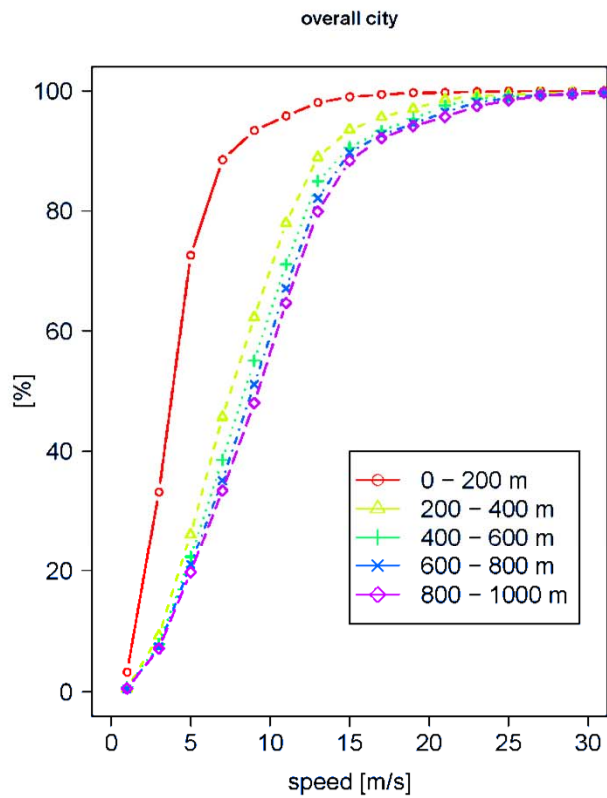
car stages > 10 [min]

$$v_{600-400} = \frac{d_{600-400}}{t_{600-400}}$$

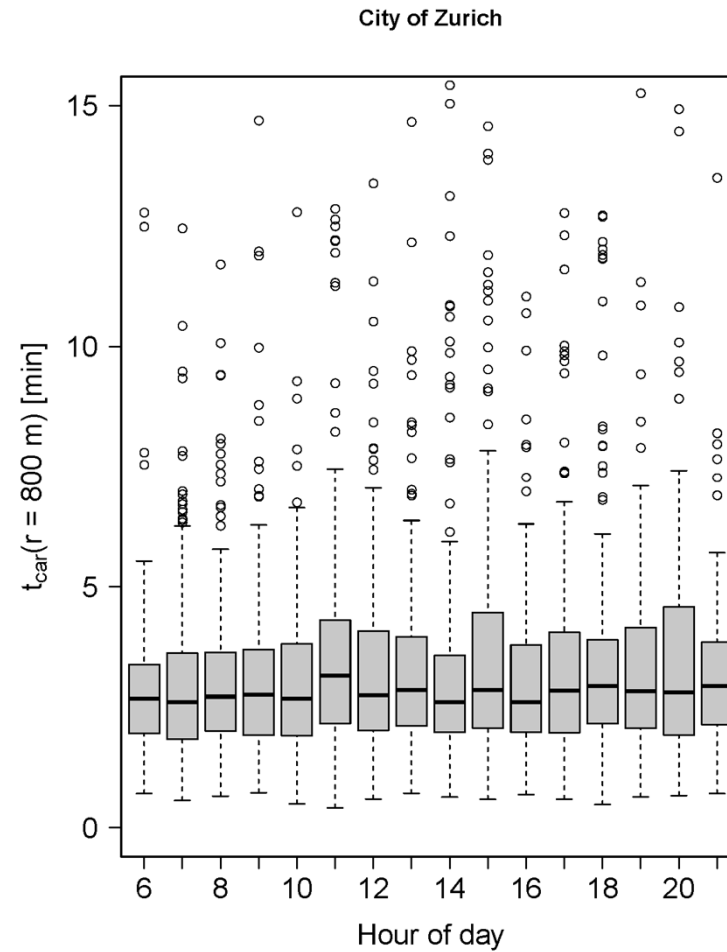
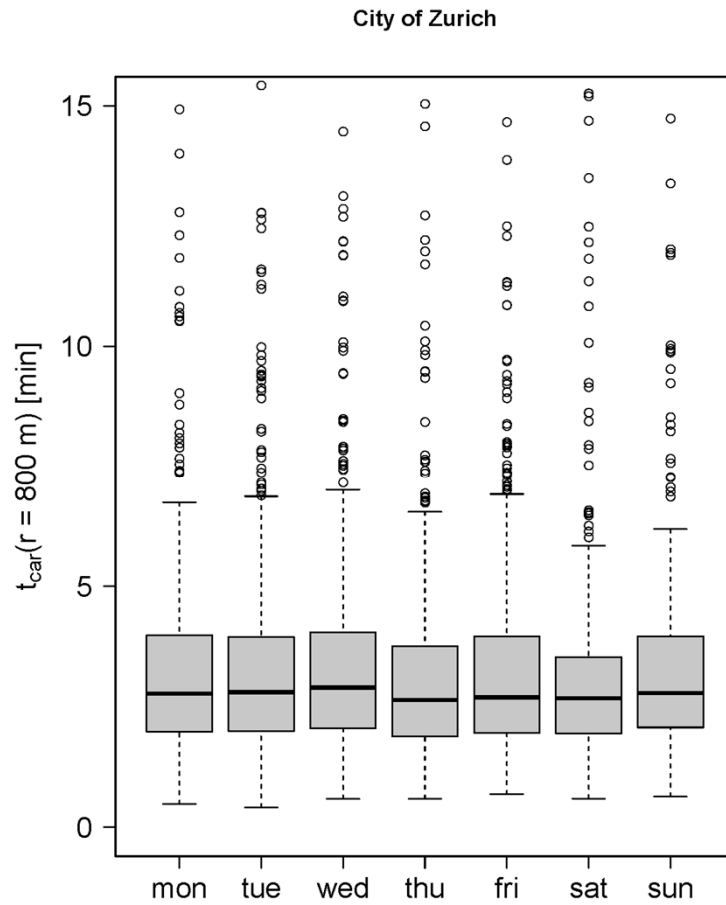




# Speed Distributions



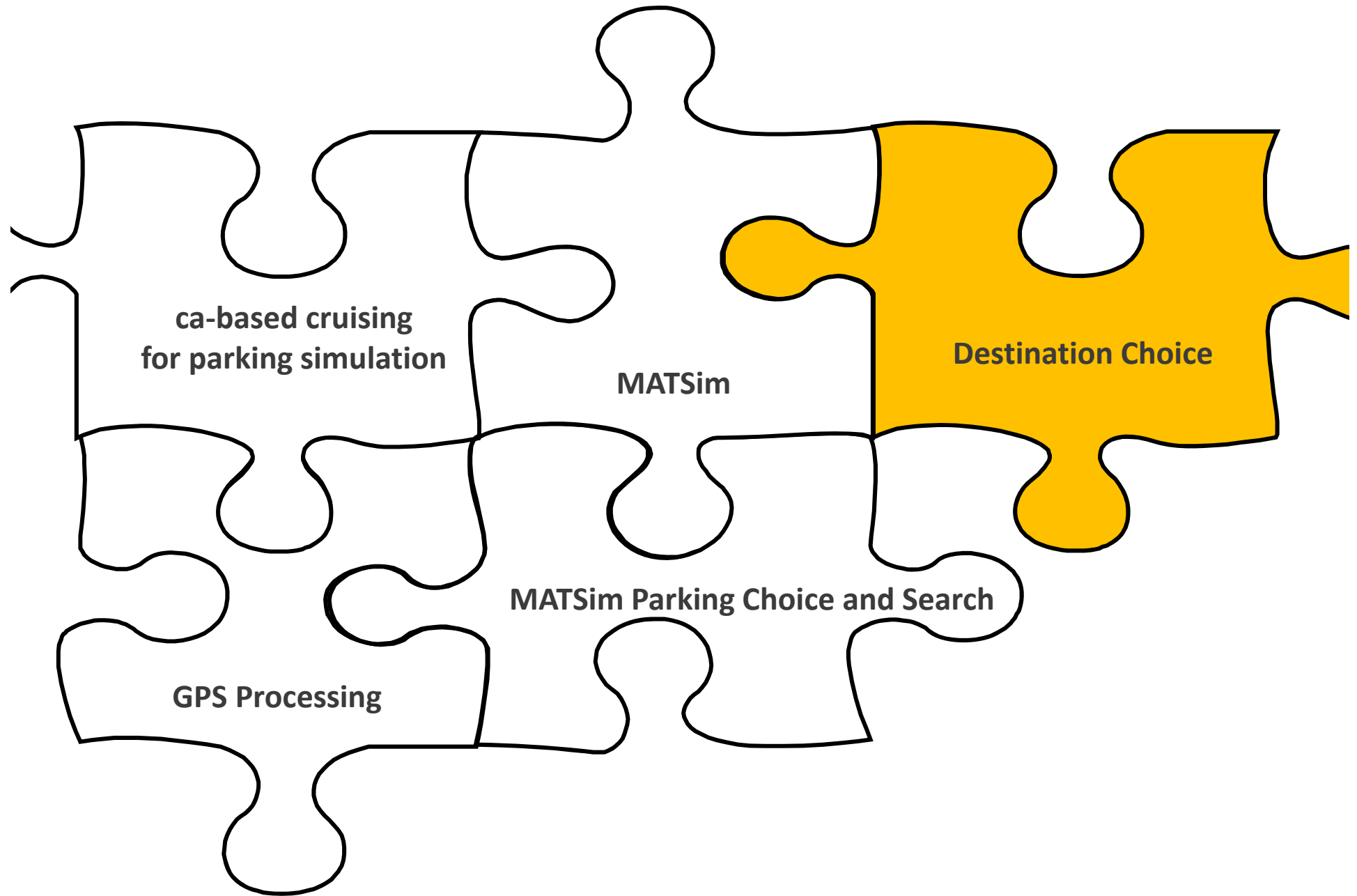
# City of Zurich – Driving Times (r = 800 m)



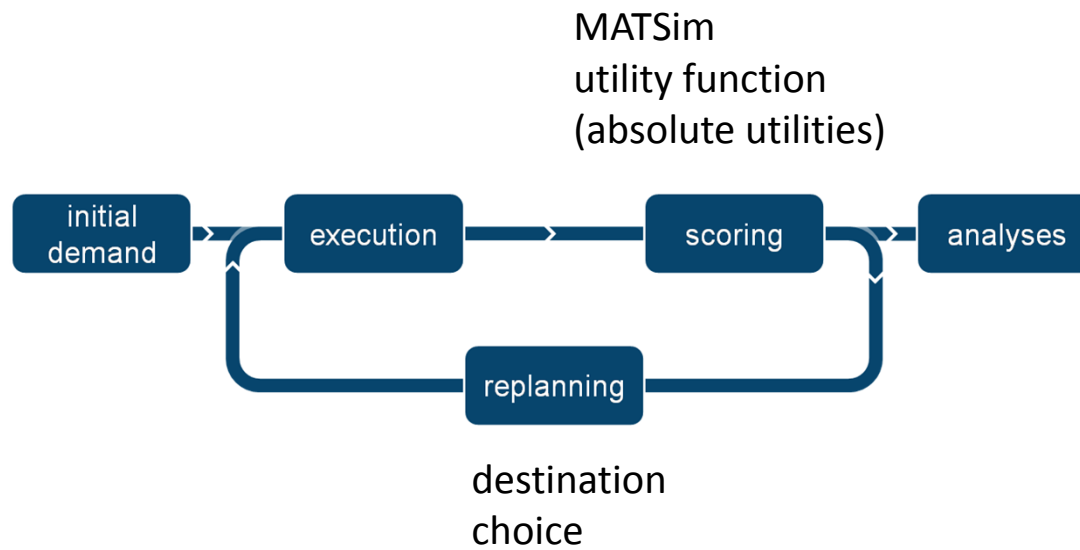
## GPS Processing and Outlook

- garage vs. on-street / private vs. public
- comparison with other cities
- usage of new IVT data set
  
- next major step: trip purpose detection

# Discussion: GPS Processing



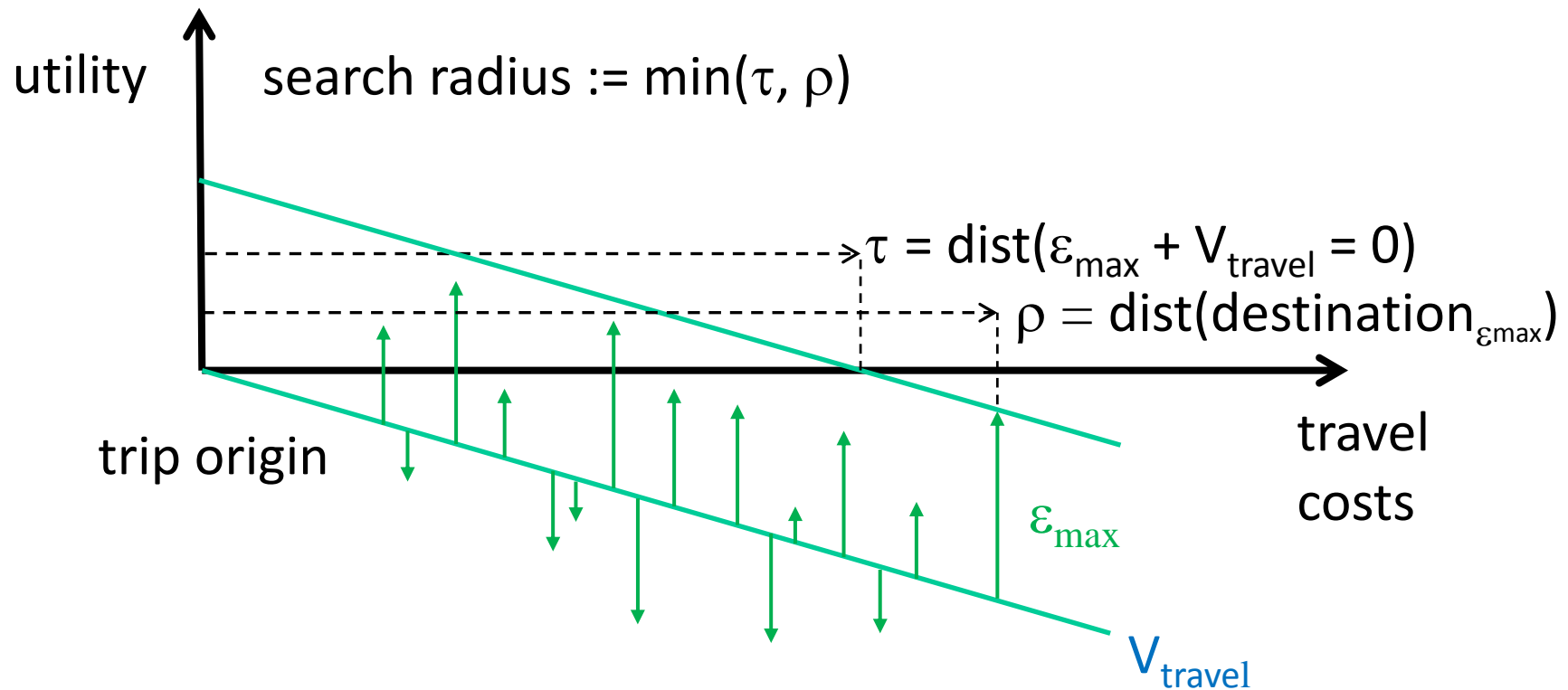
# MATSim Shopping and Leisure Destination Choice



# Unobserved Heterogeneity and Search Space

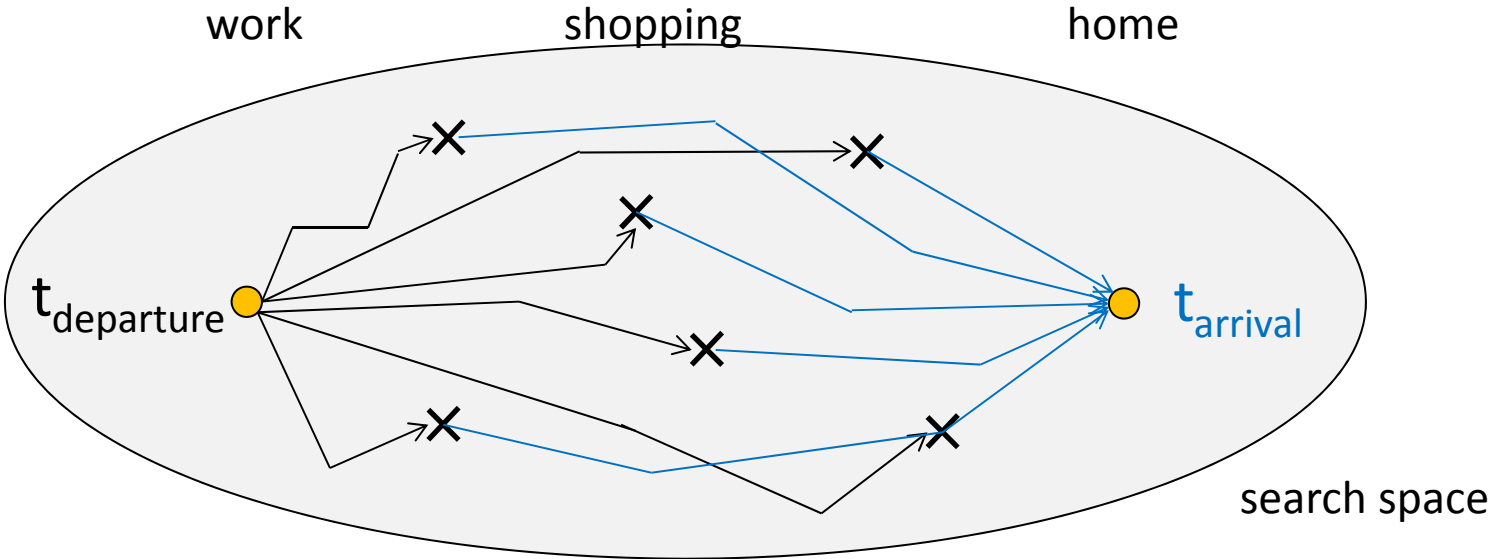
MATSim utility function

$$F = \underbrace{\sum_{i=1}^n U_{act,i}(type_i, start_i, dur_i) + \sum U_{trav,i}(loc_{i-1}, loc_i)}_V + \varepsilon$$





# Search Space Optimum



Dijkstra forwards 1-n

Dijkstra backwards 1-n

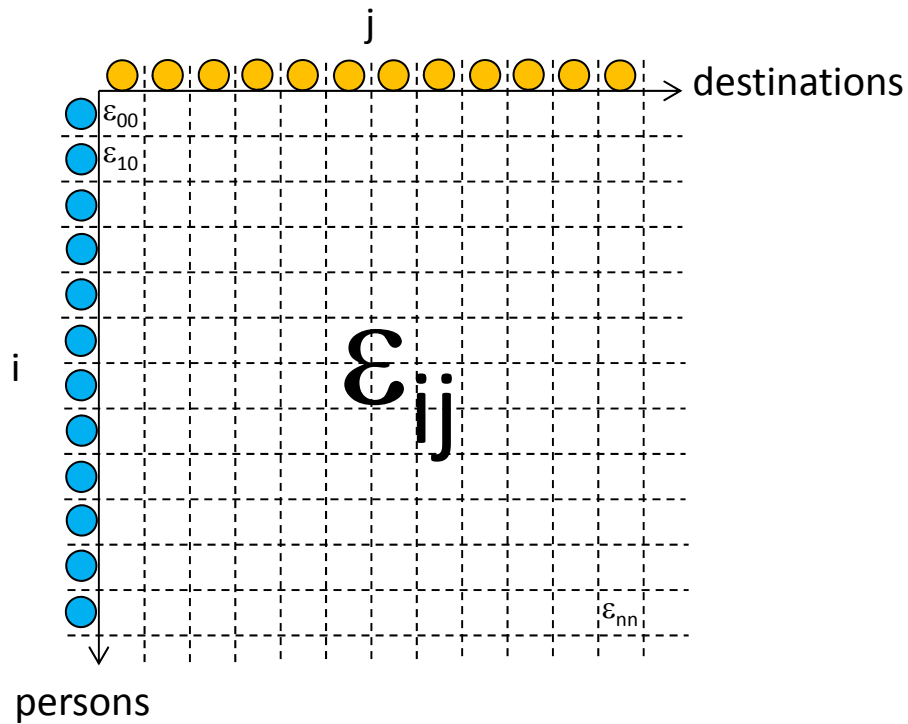


approximation



probabilistic choice

# Repeated Draws: Quenched vs. Annealed Randomness

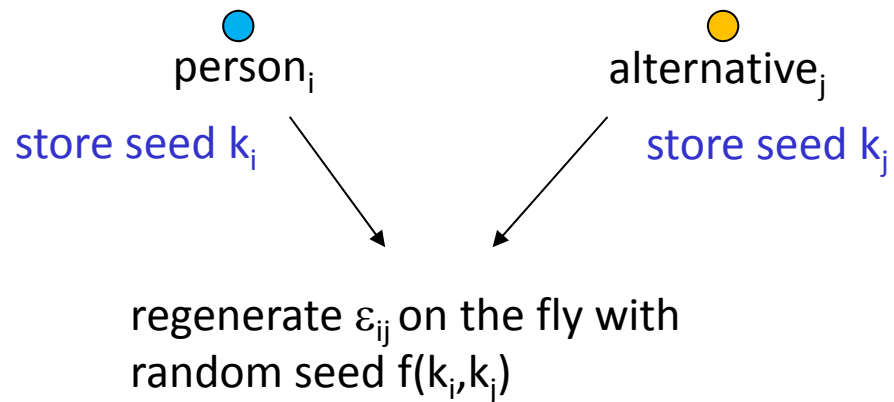


- fixed initial random seed
- ~~freezing the generating order of  $\epsilon_{ij}$~~

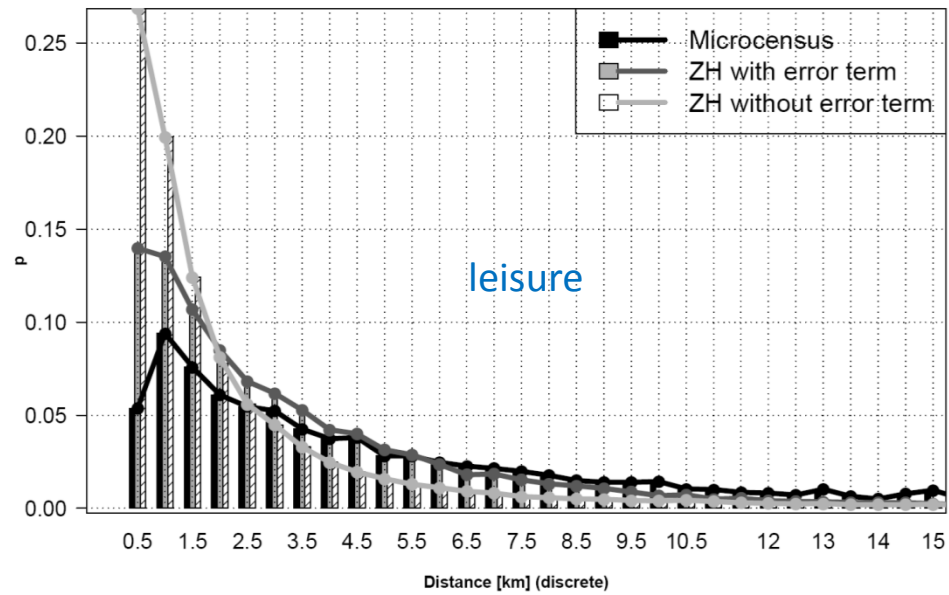
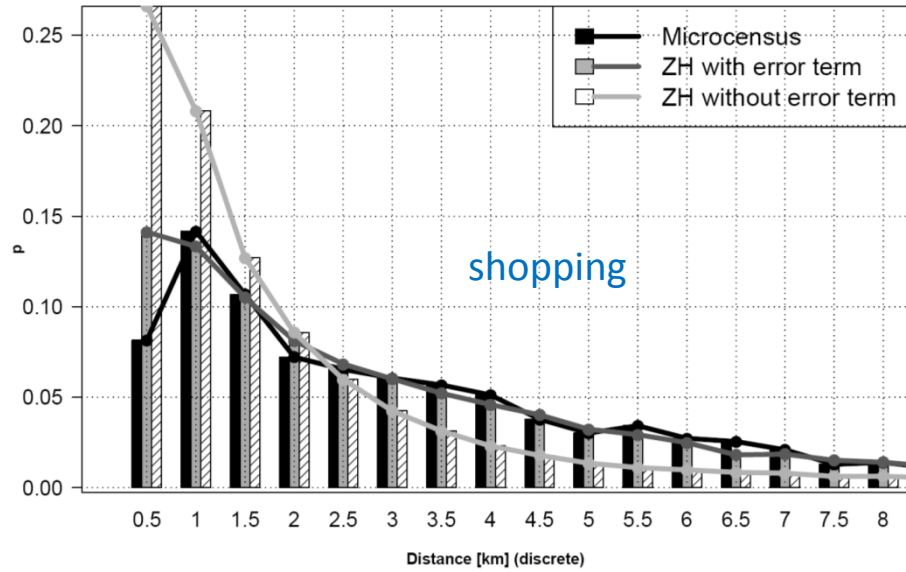
one additional random number  
can destroy «quench»

- ~~storing all  $\epsilon_{ij}$~~

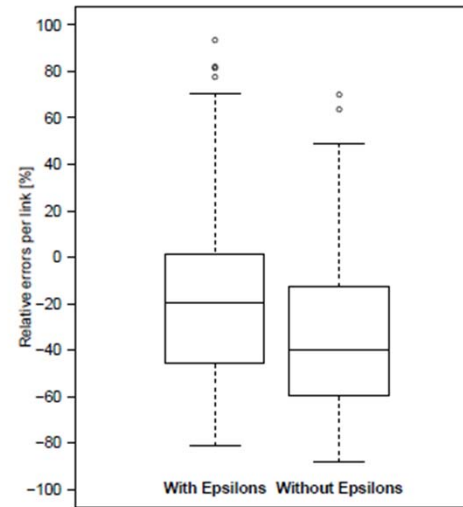
$i, j \sim O(10^6) \rightarrow 4 \times 10^{12} \text{Byte (4TByte)}$



# Results: Zurich Scenario

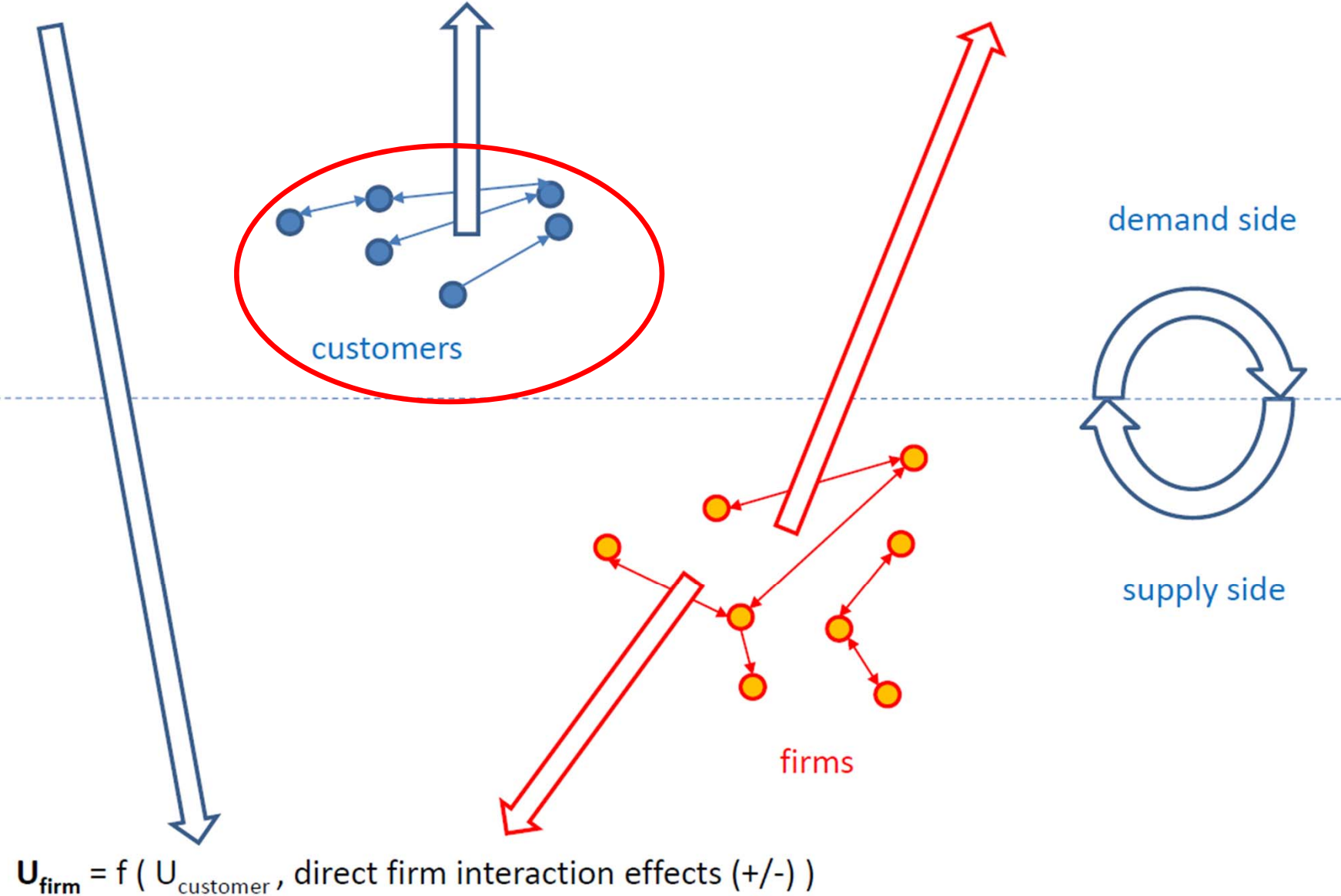


Daily traffic volumes for 123 links compared to traffic counts, iteration 100. Per link  $k$  the relative error is used, i.e.,  $(vol_{simulated,k} - vol_{counted,k})/vol_{counted,k}$ .



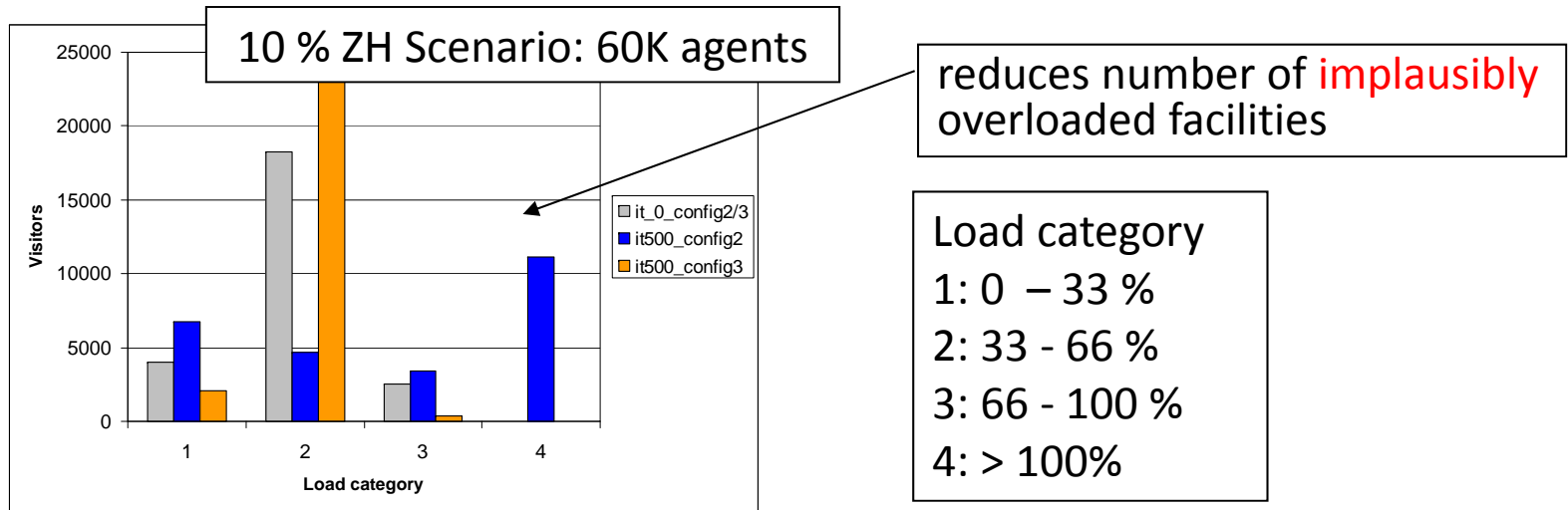
# Destination Choice Interaction Effects

$$U_{\text{customer}} = f(\text{customer interaction effects (+/-), spatial distribution of stores, ...})$$



# Destination Choice Interaction Effects

- anologon to road competition -> assignment



- positive effects (e.g., night life, sports fans, ...)
- ongoing Master thesis -> mainly studies in marketing science
- MATSim utility function


$$F = \underbrace{\sum_{i=1}^n U_{act,i}(type_i, start_i, dur_i) + \sum U_{trav,i}(loc_{i-1}, loc_i)}_V + \epsilon$$

no agglomeration terms and  $\epsilon$  iid

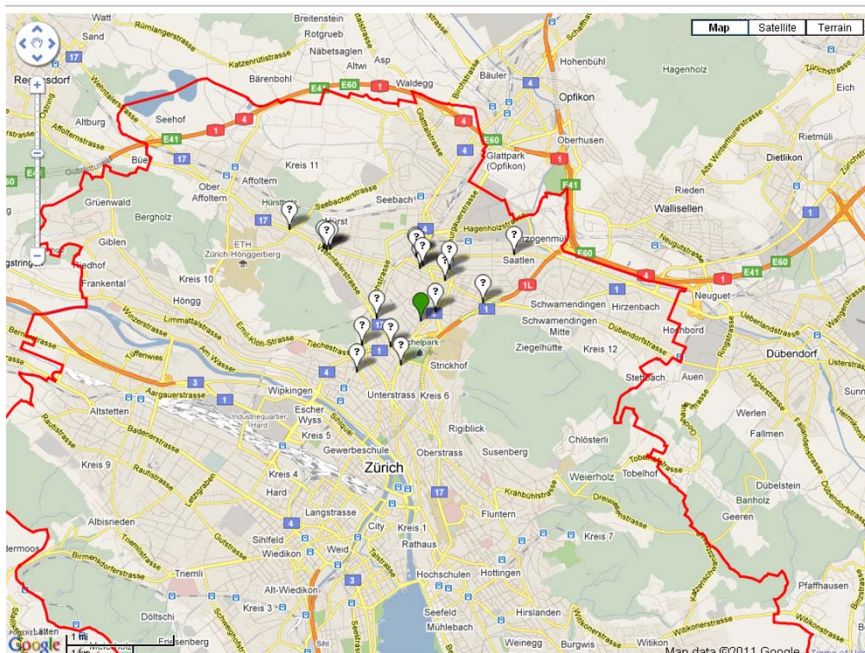
# Destination Choice: Outlook

- UTF and search space (i.e., choice set) estimation based on survey

1. Personenangaben 2. Arbeitsweg 3. Regelmässig besuchte Einkaufsläden 4. Einkaufsläden hinzufügen 5. Weitere Einkaufsläden

Hier möchten wir mehr über Ihr Verhältnis zu den Läden in der Nähe Ihres Wohnortes und zu den Läden nahe bei den von Ihnen regelmässig besuchten Läden wissen. Bitte beachten Sie, dass sich die Menge der zu bearbeitenden Läden abhängig von Ihren Antworten fortlaufend verändert. Bitte klicken Sie auf alle , und beantworten Sie die Fragen im sich öffnenden Fenster.

**Momentan sind noch 18 Läden zu bearbeiten.** Befragung abschliessen



Map data ©2011 Google

**Dhillons Quartiermarkt**



Kennen Sie diesen Laden?  
 ja  nein

Wie regelmässig haben Sie diesen Laden in diesem Jahr besucht?  
 nie  
 sehr oft (mehrmals pro Woche)  
 oft (ca. 1 Mal pro Woche)  
 gelegentlich (wenigstens 1 Mal pro Monat)  
 selten (wenigstens 1 Mal pro Jahr)

Welches sind die Gründe, warum Sie diesen Laden selten oder gar nie besuchen (Mehrfachantworten möglich)

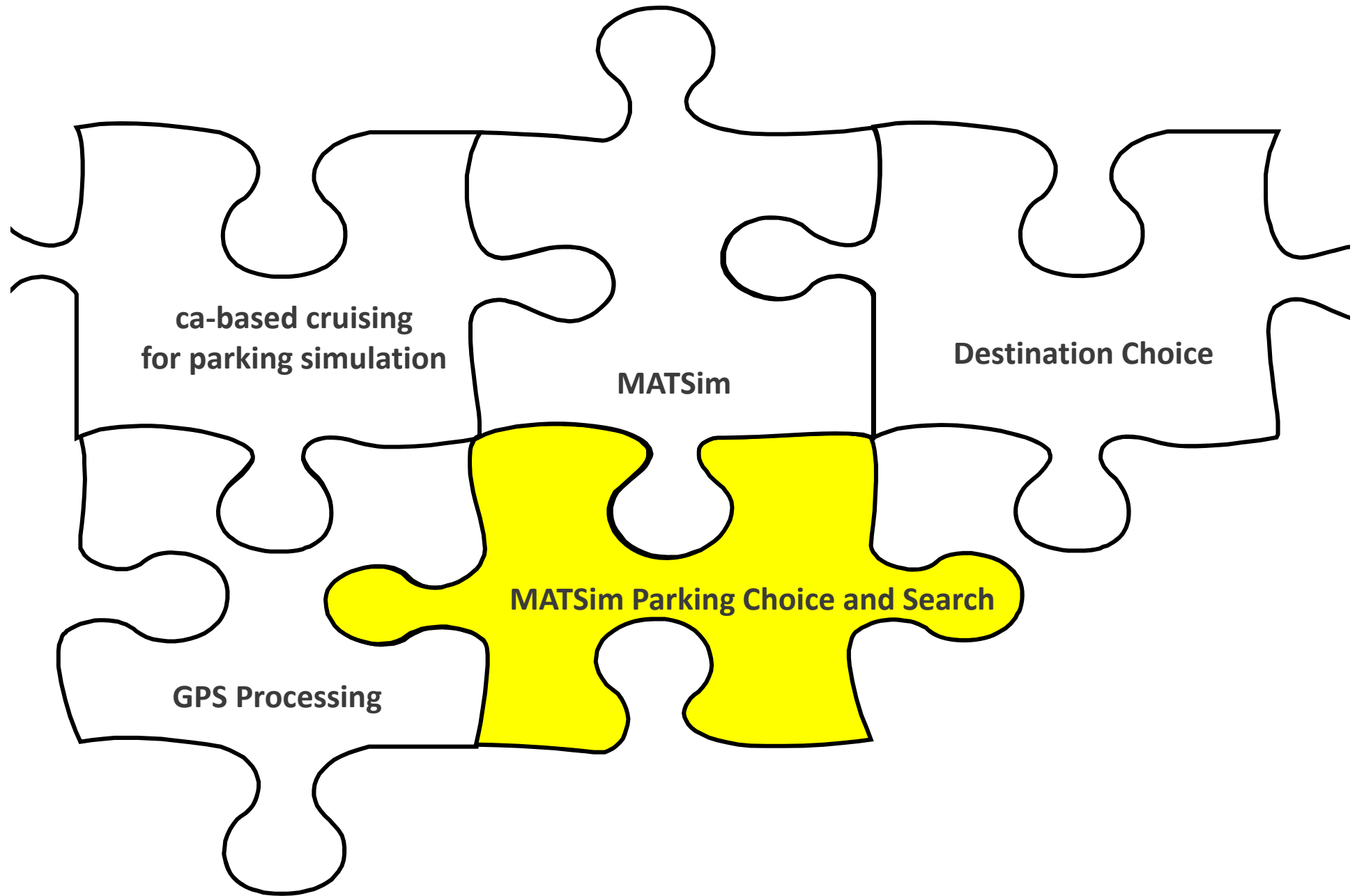
Weiss nicht, habe ich mir noch nicht überlegt  
 Mir wichtige Produkte fehlen  
 Unpraktisch, weil für mich keine Umsteige- oder Endhaltestelle (Reise mit dem ÖV)  
 Ist mir zu weit weg / liegt nicht an meinem Weg  
 Schlechtes Preis-Leistungsverhältnis / zu teuer  
 Schlechte Parkermöglichkeiten  
 Einkaufsatmosphäre gefällt mir nicht (Produktpräsentation, Platzverhältnisse, Personal etc.)  
 weitere Gründe:

Speichern und Fenster schliessen

- further interaction effects, apart from parking (master thesis)
- supply side interactions (retailers, F. Ciari)

# Discussion: Destination Choice Interaction Effects





# **Rashid's Parking Model Adventures in MATSim**

Parking Choice + Pseudo Parking Search: STRC 2010

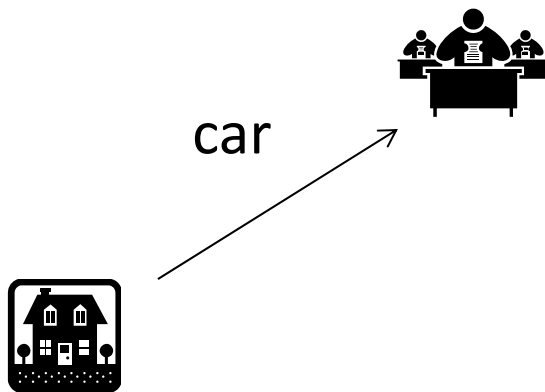
Parking Choice: Jul 2011 (for TRB)

Parking Search: IATBR 2012/ Jul 2012 (for TRB)

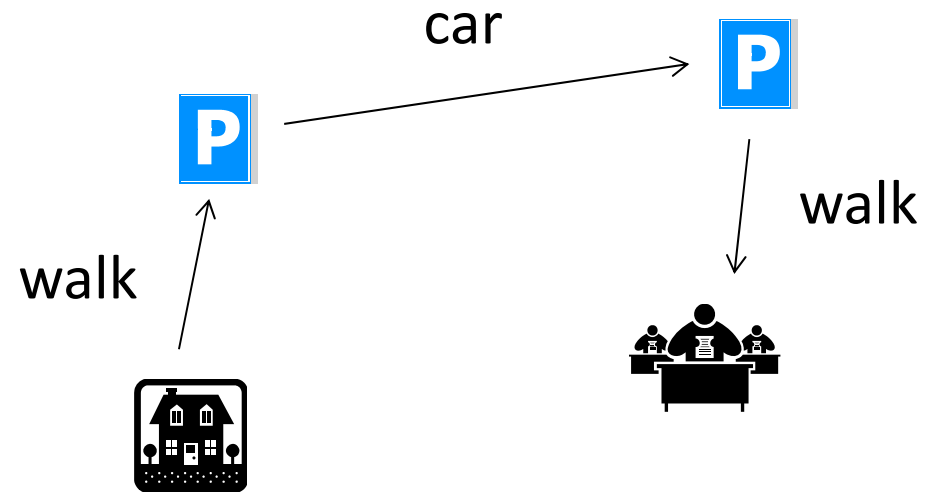
Parking Choice vs. Parking Search

# Parking Choice + Pseudo Parking Search: STRC 2010

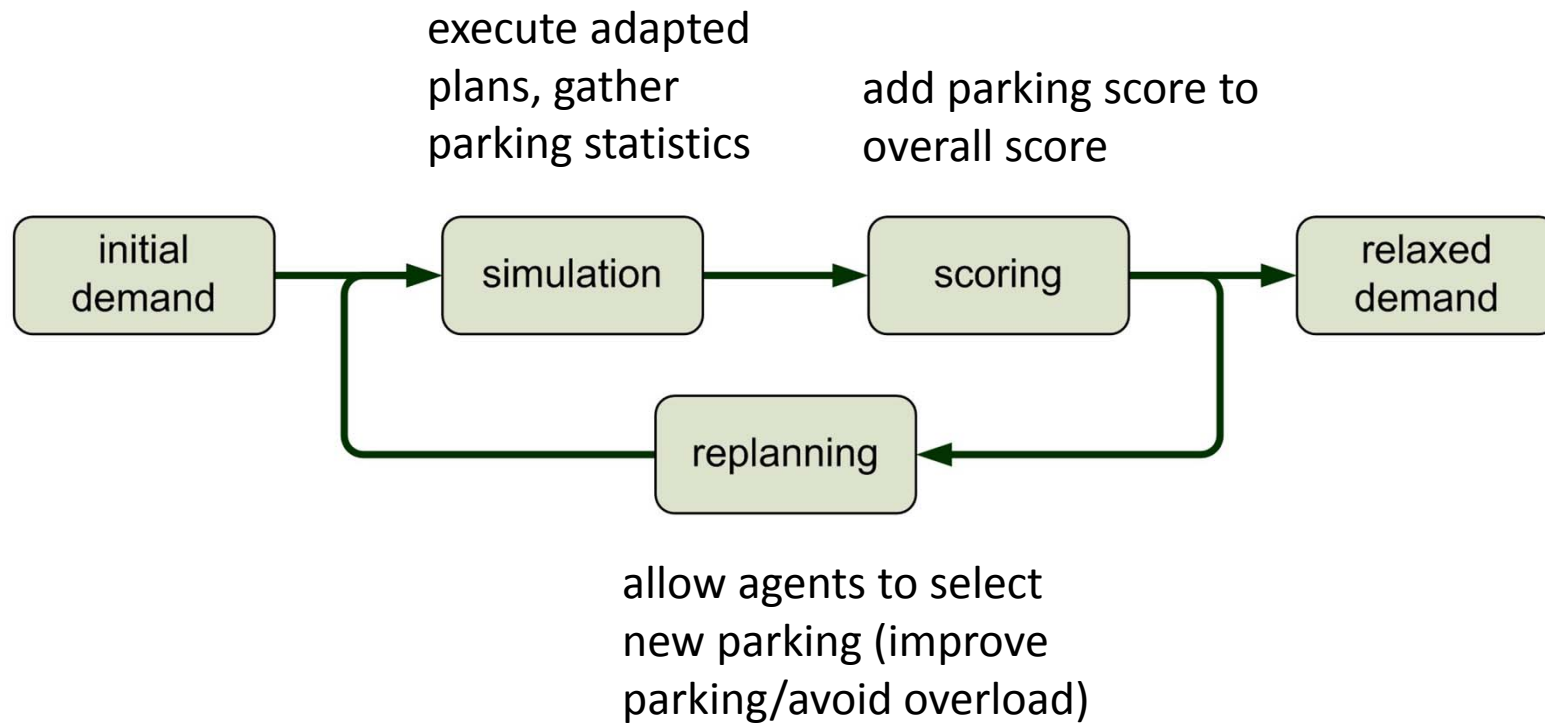
original MATSim plan



adding parking acts + walk legs



## Parking Choice + Pseudo Parking Search: STRC 2010 (con't)



## Parking Choice + Pseudo Parking Search: STRC 2010 (con't)

### Feature Summary:

- agent's plan changed
- Basically just try find parking which gives good utility (walk dist, price, etc.)
- if parking capacity violated, try assigning potentially empty parking (e.g. further away).
- incorporation of pseudo parking search paths possible

### Major drawbacks:

- other strategy needs to know about parking or you have to think about all possible applications of your module and provide replanning strategies for them (not extendable).
- slow adaptation to overloads.

## Parking Choice: Aug 2011 (for TRB)

Both major shortcomings solved:

- Simulate the occupancy of parking, as people arrive (no parking overload possible!)
- selection between public, private/reserved and preferred parking types
- parking selection according to best utility
- feedback to MATSim (e.g. mode change possible).
- applied on Zurich scenario -> helped to reduce car traffic in areas, where in reality little parking is available (solved problem within EV project).
- use post-processing to add the foot/correct car route
- good performance, independent of micro-simulation

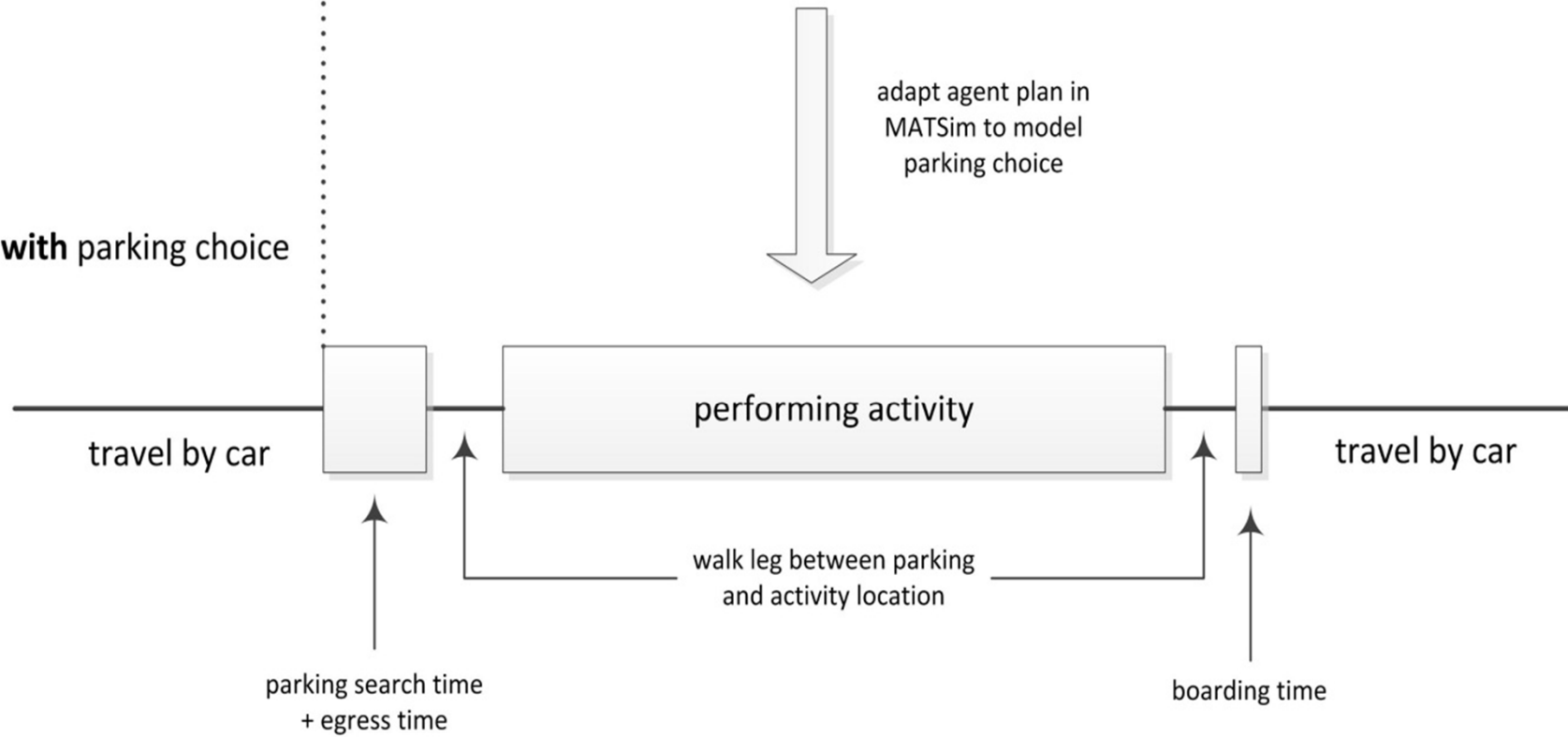
[TODO: Experiment with Random Error Terms, try reusing work of A. Horni (2011)]

# Parking Choice: Aug 2011 (for TRB) – con't

without parking choice



with parking choice





## Parking Search – Starting Point

- Lot's of data collected on parking search (e.g. at IVT):
  - Axhausen (1989): Parking search strategies
  - Axhausen and Polak (1991): Decomposing parking search into components (e.g. parking search time, walking time, parking cost, etc.) and different valuation of these components
  - C. Weiss (2011): willingness to pay for search time reduction high for very short activities, higher income people willing to pay more for this, etc.
  - L. Montini (2012): «Searching for parking in GPS data»

# Agent-based Parking Search

- Only a few
  - Benenson I., K.Martens, and S.Birfir (2008)
  - Spitaels, K., Maerivoet, S., De Ceuster, G., Nijs, G., Clette, V., Lannoy, P., Dieussaert, K., Aerts, K., Steenberghen, T. (2009)
- Challenges/Questions
  - How to model personal preferences, individual valuation of parking components, etc.?
  - Is just one search strategy enough?
  - How to built a system with more than one scenario in mind?

## Parking Search Model Requirements

- Modelling individual preferences and individual valuation of parking components
- Allow modelling more than one parking search strategy; different parking search behaviour at different activities possible (e.g. home, shopping)
- Allow making trade-offs between parking strategies
- Also allow incorporating observed behaviour into model without trade-offs (fixed assignment of strategies to share of agents or groups)
- Parking search should have effect on longer term decisions (e.g. mode choice, location choice, etc.)
- Reserved parking, preferred parking (e.g. trade-off for EVs for parking with plug)
- Agent should respond to policy change: E.g. price, capacity change, law enforcement increase, no parking provided at work, etc.

=> Need to model a framework, which has all the necessary components to allow such simulations

## Parking Search in MATSim

- Based on Within-Day replanning framework, C. Dobler (2011)
  - Interfaces for agents to act as they drive
  - Parallelization
- Don't change the plan, but only the execution (through strategy)
- Allowing implementing multiple parking strategies
- Individual preferences of agents can be incorporated in utility function, which includes terms for walking distance, search time and cost

## Scenario Setup

User defines, which agent can use which strategies at which activity.

Example:

**home:** search for street parking (non-metered) - as agent has residence parking card for area close to home.

**work:** drive to parking provided by company - no parking search needed

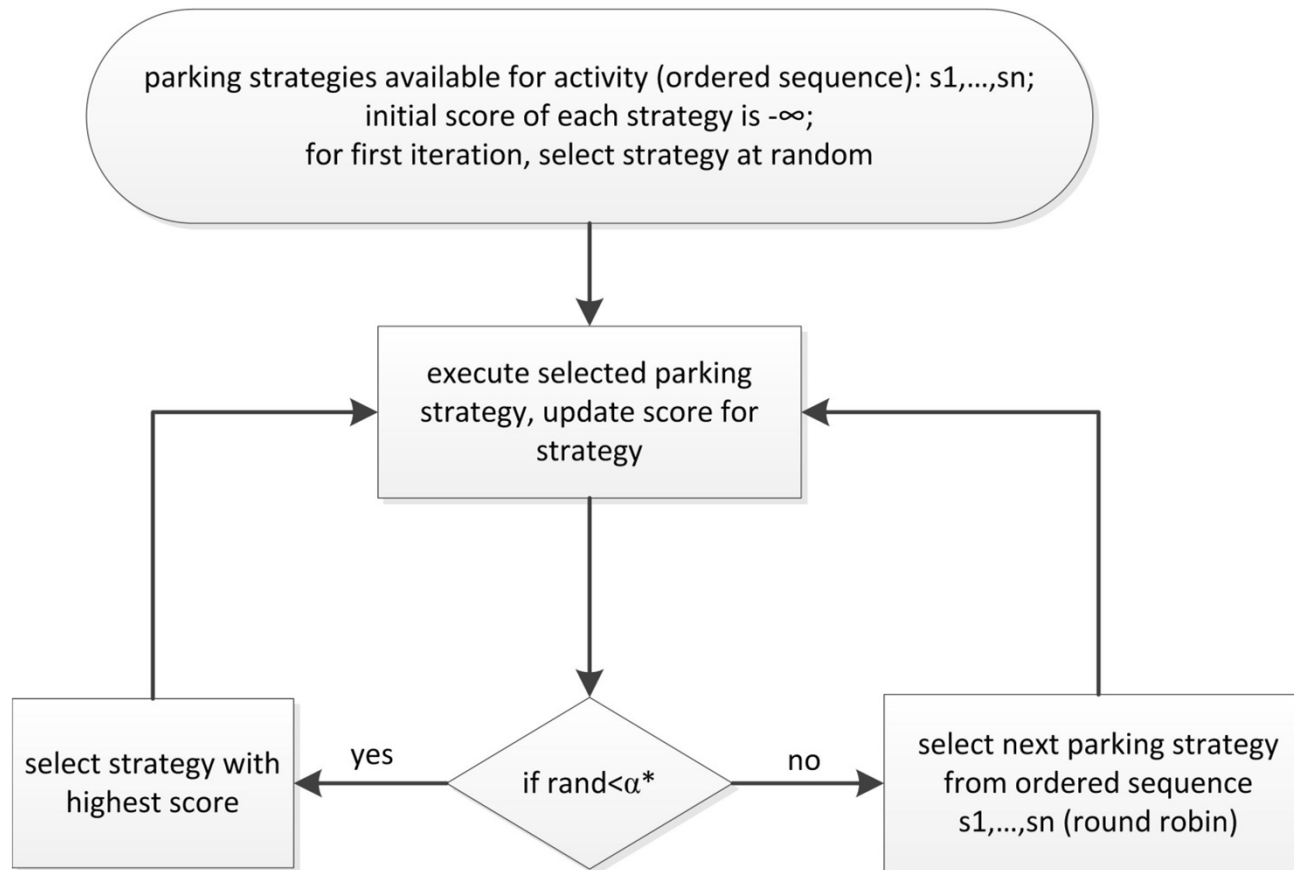
**shop:** 4 parking strategies available:

- search for street parking only (free + metered)
- garage parking
- combined street parking search with last resort garage parking
- illegal parking

## Evaluating parking strategies

- make sure, that you don't have too many strategy changes after each iteration, so that system can «relax» (similar condition to MATSim replanning).
- make sure, that if we stop the simulation at an iteration, with high probability a parking strategy is executed which is optimal (based on experience from strategies evaluated till that point).
- make sure, that each strategy is re-evaluated after some time, so that the strategy can be executed and scored for the «fresh/updated» environment of the agent

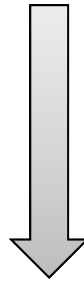
## Evaluating parking strategies (con't)



\*) this value can be adjusted within limits: «too high» and «too low» values can both lead to undesirable results (unfrequent score updates resp. no focus on best strategy). Value of 0.9 is recommended based on experience from MATSim replanning.

## Policy Changes (Example)

**work:** drive to parking provided by company - no parking search needed



New company  
policy: No free  
parking for  
employees

**work:** 3 parking strategies

- rent parking from company
- search on-street parking (high probability route set)
- search on-street parking and garage parking as last resort

(mode change, arrival time change, etc.)



## Utility Function

$$U_{parking,i} = U_{P_{cost},i} + U_{P_{searchTime},i} + U_{P_{walk},i} + \epsilon_i$$

$U_{P_{cost},i}$ : fixed rent/one-time cost (can depend on parking duration)/monetary fine/can also involve activity duration (willingness to pay changes)

$U_{P_{searchTime},i}$  and  $U_{P_{walk},i}$ : modelled explicitly (although there is already implicit disutility in default MATSim scoring function) => individual valuation of different search components.

parking search time variance: could be part of  $U_{P_{searchTime},i}$  (stable medium search time vs. high variance in search time)

## Current Work

Implementing framework/strategies:

- > Search free parking (e.g. high probability route)
- > Search both free + paid parking
- > Search street parking with last resort garage parking
- > drive to optimal garage parking (trade-off walking distance, price)
- > directly drive to optimal parking (perfect knowledge)
- > random search
- > etc.

IATBR: Test cases, which demonstrate, that the search framework works  
- model is sensitive to policy changes

=> TRB: Setting up Zurich Scenario

## Discussion: MATSim Parking Choice and Search

- applying which concept?
- simulation costs?
- only walk trips PP-> Act
- parking studies

