Large-scale shared autonomous vehicles systems and transportation modelling implications

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What do we really expect from AVs?

AVs: user perspective

Expectations

Automated vehicles will provide…

- Cheaper individual mobility
- Comfortable travel
- Fast point-to-point travel
- More safety
- Less congestion
- …

Possible usages

- Automated taxi (kids, elderly, impaired)
- Robot functions
    - Pick-ups and drop-offs
    - Parking
    - Refueling
- Fall-Back-Function
- “Office / Home on Wheels”

Adaptet from: Axhausen, 2017

AVs: supply side perspective

Existing transport modes might coexist with (and at a later point might be supplanted by):

- AV as private vehicle
- AV-taxi (car sharing)
- AV-collective taxi (Hop on/off) (ride sharing)
- AV- on demand in different sizes
- AV- Line buses
- Trains with ETCS

AV and IT allows flexible demand bundling by:

- Vehicle size
- According to WTP for
  - Waiting time
  - Access time
  - # Persons in the vehicle
  - Travel-time
  - Comfort

Redistribution of the demand between current transportation companies and new ones (consolidation of TNC, emergence of MaaS companies, possible paradigm change for car manufacturers)

Adaptet from: Axhausen, 2017

SAV as the only motorized mode?

Some researchers expect different forms of autonomous travelling converging towards a universal travel mode of on-demand autonomous vehicle services (Enoch,2015), which can be seen as a completely new mode of transport (Skinner and Bidwell, 2016)

Indeed, many studies focused on shared autonomous vehicles fleets as a substitute of a large part, or even all privately own cars (Fagnant and Kockelman, 2015, Kornhauser et al., 2016, Bösch et al., 2017, Bischoff et al., 2017, Hoerl et al., 2018)

→ Easier to represent than other possible futures and yet insightful

If we want to plan for such a system, which kind of model do we need?

Modeling requirements: some ideas

- Model individual vehicles, individual users
- Capture the supply/demand dynamic (go beyond the concept of a known and fixed demand and a supply to be optimized according to it)
- Model this as part of the whole transportation system

Zooming out a bit…

Transportation planning (I)

Observations:

For a long time transportation planning = infrastructure planning (Dubbed as “predict and provide”, Owens, 1995)

Infrastructure should be effective (it serves the purpose adequately) and efficient (it does so minimizing the resources used) → size the road infrastructure based on situations which are “challenging” for the system and are “recurring regularly” → concepts like “Peak hour”, “N-busiest hour”, “Average working day” are used.

Transportation planning (II)

Observations:

Activity based travel demand models theory, in the 70s → travel demand is the consequence of activities that travelers want to perform at different locations and that a full understanding of a transportation system, implies dealing with individual full day schedules.

From the beginning of the 21st century increased awareness that planning should use comprehensive models, to have a more complete vision of infrastructural and policy decision impacts and capture travel related externalities. → In some countries revised guidelines. (i.e. “context aware planning”).

Transportation planning in an SAV world

Observations:

Cars are not mere users of the infrastructure anymore but in a way part of it

Until now SAV modeling efforts focused on one day (at most)

In such studies not much reflections were spent on different functions fulfilled by privately owned vehicles in the current transportation system

Questions:

What kind of recurrent situation do we need to take into account to plan an SAV based transportation system? What kind of functions?

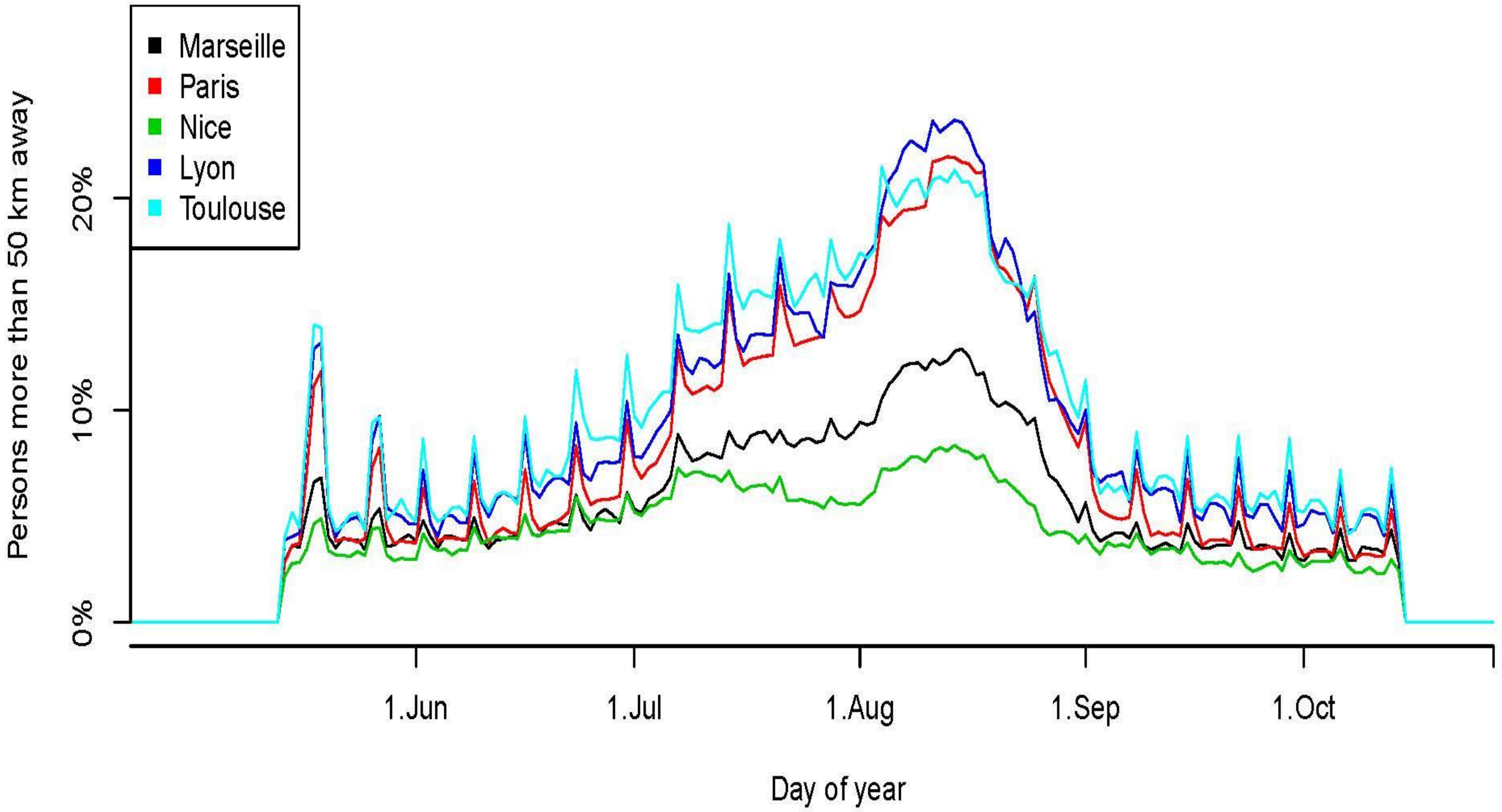
And back to the point…

A vision of an SAV world

Hypothesis:

- A fleet of SAV provides the bulk of mobility needs to the population, in combination with few public transport options (main lines urban and extra-urban) and human powered modes (urban).
- No private vehicle ownership exists anymore.
- A ratio of 1:10 (AV/Individuals) is enough to provide a reliable and convenient transportation service within a region (Fagnant and Kockelman, Kornhauser et al., Bösch et al.)

A summer in France: the fleet flees away…



…how to cope with it?

Given the SAV world sketched before, what happens if a substantial amount of users would need to travel with an SAV out of the region of origin?

a) Business as usual: They go by SAV and keep it for use at destination
b) Independent systems: The destination is reached by another transportation mode, a SAV system is available at destination
c) Integrated system: They reach their respective destination by SAV, the SAV is dispatched back, another car (SAV) is available at destination

Some issues

a) Business as usual: They go by SAV and keep it for use at destination

Issues: Level of service at origin

b) Independent systems: The destination is reached by another transportation mode, another SAV is available at destination

Issues: Capacity of other modes, fleet size at destination

b) Integrated system: They reach their respective destination by SAV, the SAV is dispatched back, another SAV is available at destination

Issues: Massive total VMT increase, arguably negative impact on (highway) congestion, fleet size at destination

→ Demand scenarios currently used to answer certain questions are inadequate from time horizon, vehicle functions and possibly also geographic extent perspectives

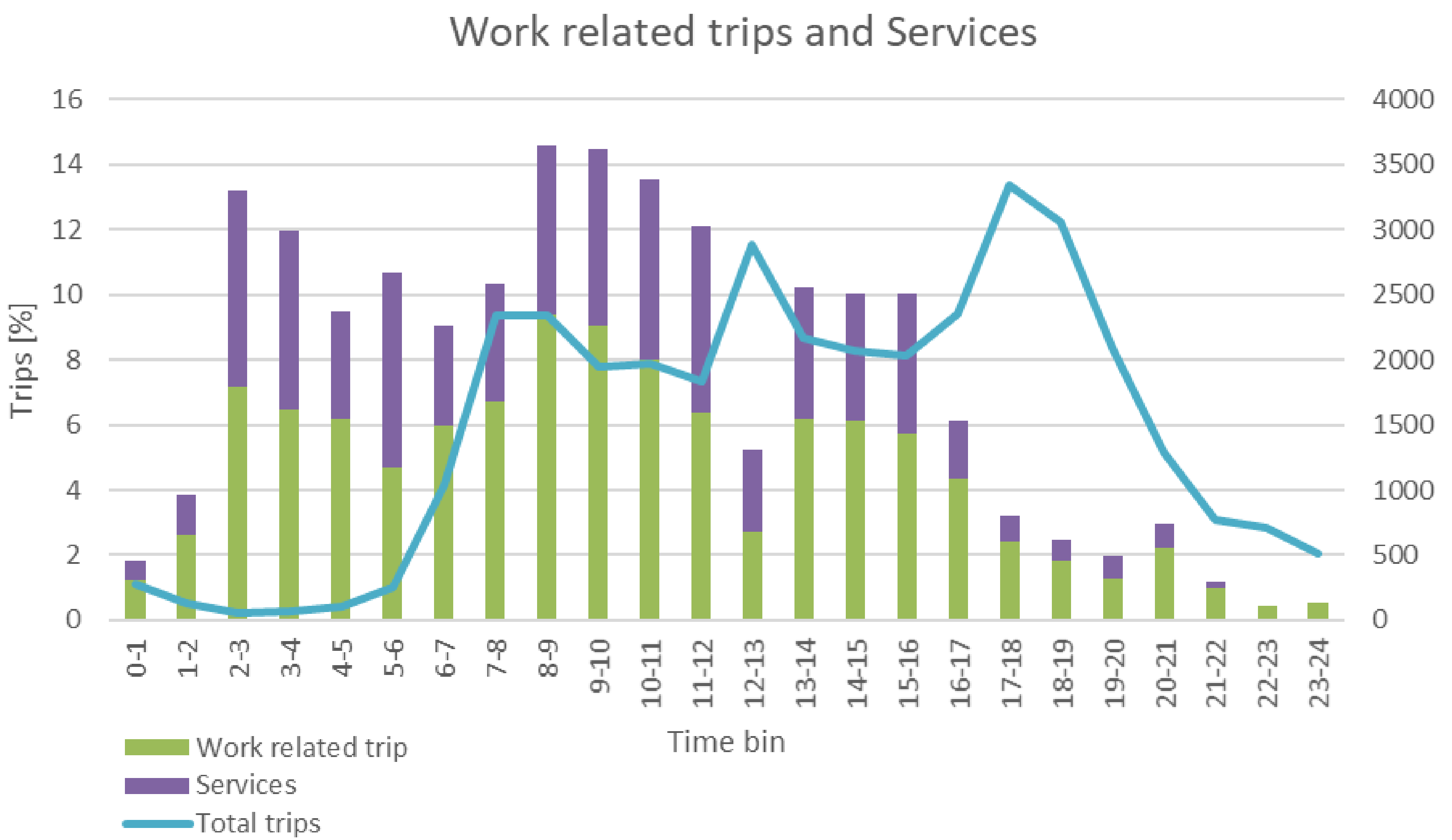
Other relevant issues

Are all vehicles sharable?

Observation:

Currently models generally ignore vehicles used by public servants, craftsmen and other not personally owned vehicles (10-20% of the vehicles excluding public transit). Such vehicles are possibly/likely not sharable (unsharable)

→ If all what we need is to know traffic flows to plan infrastructure, this is a minor problem, but what if we assume that all motorized transportation demand is fulfilled with a shared fleet?



Work related and service trips [in % of the total amount of car trips] at a certain time of the day (Individuals surveyed on Monday to Friday).

Unsharable vehicles

The data showed, suggests that the fleet size of the AVs based system is in the same order of magnitude of that of all unsharable vehicles → the latter cannot be neglected anymore. In particular, they should not be confused with other vehicles in the models

→ New insight on such mobility (i.e. mobility patterns) should be gained, explicit modeling could be considered

What externalities should we consider?

Currently vehicles' manufacture footprint is a second order impact, since the fleet is not a planning dimension, and depends on individual choices and is therefore ignored

In a SAV fleets based system, fleet size is a planning dimension and part of several (SAV systems specific) trade-offs (for example, # cars vs. level of service vs. VMT)

A shared fleet will need to have a quicker vehicles turnaround

Models should at least support, if not directly provide, instruments to quantitatively assess such trade-offs → Life Cycle Assessments (LCA) could be plugged-in/integrated in transportation models

Discussion

Temporal scope of the models

A temporal scope over one day in transportation modeling is uncommon. This would capture more fluctuations in the daily patterns within urban areas as well as long distance travel. The latter generates a large part of total VMT, but research efforts has been sparse in this area. Yet, given the SAV world sketched:

→ we should try to use multi-day simulations in order to understand which situations (i.e. day sequences) are relevant for planning

→ (Big) longitudinal Data → Smart phone, Social media, Traffic counts, Connected vehicles, MaaS, etc.

→ This perspective is necessary not only under the hypothesis that all motorized transportation modes will converge toward SAV systems, but just if this is deemed as an hypothesis worth assessing

How many AVs will we really need?

Many of the existing studies found values of 10% or even 5% of the current privately owned vehicles fleet

Studies following up the one presented here (Bosch et al, 2018; and Bosch, 2018)[1] looking at different scenarios where certain policies would be implemented (price levels, road pricing, ban of private vehicles, subsidies levels, etc.) found a broader range (5% to 50%).

But even accepting the 10% value to which many studies converge, the arguments discussed here would suggest that it will be difficult to go below 20% or even 30%

1

Bosch, PM, F. Ciari and KW Axhausen (2018) Transport Policy Optimization with Autonomous Vehicles, *Transportation Research Record*

Bosch, PM (2018) Autonomous Vehicles-The next Revolution in Mobility, ETH Zurich.

How many elephants in the room…?

- Temporal scope of the models
- Unshareble vehicles
- LCA

- Geographic scope of the systems (and of the models)
- Induced demand (New user groups, Ryanair or Telecom approach)
- Evacuations
- …

Some facts about modern transportation

Ford T-Model was introduced in 1908

The first limited-access, high-speed road network in the world, (Autobahn form Frankfurt am Main to Darmstadt) opened in 1935

Eisenhower's Federal Aid Highway Act was signed in 1956

Transportation planning started being recognized as a specific discipline in the second half of the 20th century.

→ Some of the events which defined automobility happened either before or at the very beginning of the existence of transportation planning as we intend it today

Transportation modeling and the AVs revolution

Competely different than at the wake of automobility, transportation planning has become an important discipline within civil engineering and widely present in the public discourse.

→ The incredible level of interest that AVs have attracted within the research community is good news and might help avoiding the errors of the last century (that we are still paying for!)

→ Yet, a large part of the research is moving along the lines of what we were doing with the current transportation system, not necessarily considering the peculiarities of a transportation system in which AVs would be the backbone

Transportation modeling and the AVs revolution

Automobility has a huge impact in how our cities are built, our choices regarding mobility are made, our whole life is structured.

A transportation system based on sharing could change this much more profoundly that we thought so far. To plan for that we need to think better at the specification of the problems we need to solve.

The work so far is useful for modeling SAV operations and can also be the basis for multiday approaches

Many of the interpretations and policy recommendations provided so far will probably need to be revised

A more detailed discussion on my take on SAV specific model requirements can be found in:

Ciari, F., M. Janzen and C. Ziemlicki (Forthcoming) Planning shared automated vehicle fleets: specific modeling requirements and concepts to address them, in “Demand for Emerging Transportation Systems”, Antoniou, C. and D. Efthymiou eds., Elsevier.

A complicated review process in which I got reviews either like a) or like b)

a) Timely paper which provides very useful ideas on SAV modeling
b) Intriguing title but silly arguments

A person who never made a mistake never tried anything new

(A. Einstein)

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All models are wrong, but some are useful

(G. Box)

Thank you for your attention!

Why shared mobility?

Research Goal

- Build a **policy sensitive model** that can support planners and policy makers **assessing** possible **future shared mobility scenarios**

Motivations: why modeling shared mobility?

- Still small but conceptually "**mainstream**" ("Sharing economy")
- Fits well with some **societal developments** ("Peak car")
- Is often mentioned when it comes to make transport more **sustainable**
- The **actors** involved are increasingly **large** → Able to have a "big bang" approach (implies **large investments**)
- The level of **competition** on the market is increasing → **Higher** investment **risk**
- Shared mobility is **evolving fast** → Uncertainty about i**ntegration/competition** among different modes/systems (i.e. MaaS)
- **Autonomous Vehicles** will be shared vehicles?

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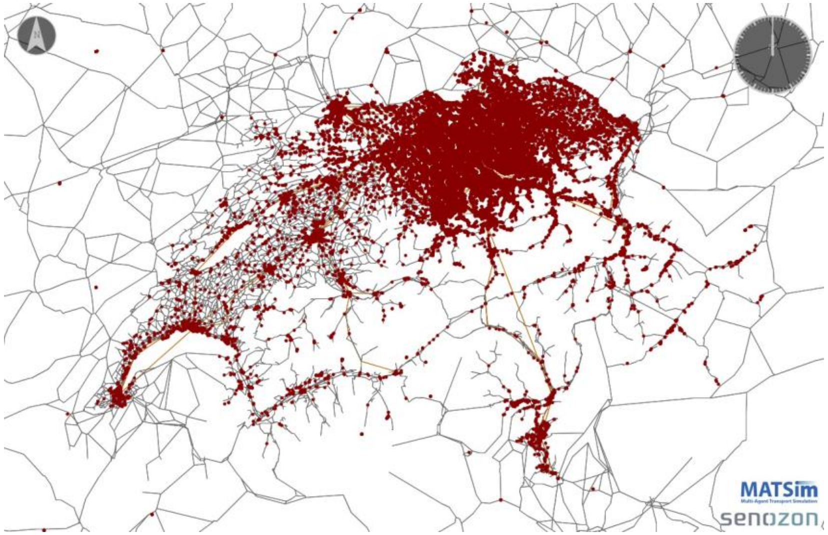
AVs as shared vehicles: the fleet size problem

Bösch, P.M., F. Ciari and K.W. Axhausen (2016) Required Autonomous Vehicle Fleet Sizes to Serve Different Levels of Demand, TRR 2542 (4) 111-120.

Goals:

- **Sizing** a **SAV fleet** which would replace part of the personal vehicles fleet
- Get insight on the **level of service** and the possible **trade-offs**

Scenarios – Area



Total population Zurich Scenario: 1.3 Mio. Agents with 3.6 Mio. Trips

Simulated **demand** levels:

- 1% to 10% in 1% intervals
- random sampling of agents

Simulated **supply** levels:

- AVs provided as a fraction of the # of agents
- 10% to 100% in 10% intervals
- plus 5%, 15%, 25%, 35% levels

Ten different random seeds used

=> Total 1’400 simulations

Simulation Framework – A typical Trip

Initial distribution of AVs randomly at home locations of agents

Registering of a new Request

5 minutes before planned start of trip

↓

Search for a free AV and Dispatching

Shrinking search radius, no reevaluation after dispatch

↓

Drive of AV to Start Location of Trip

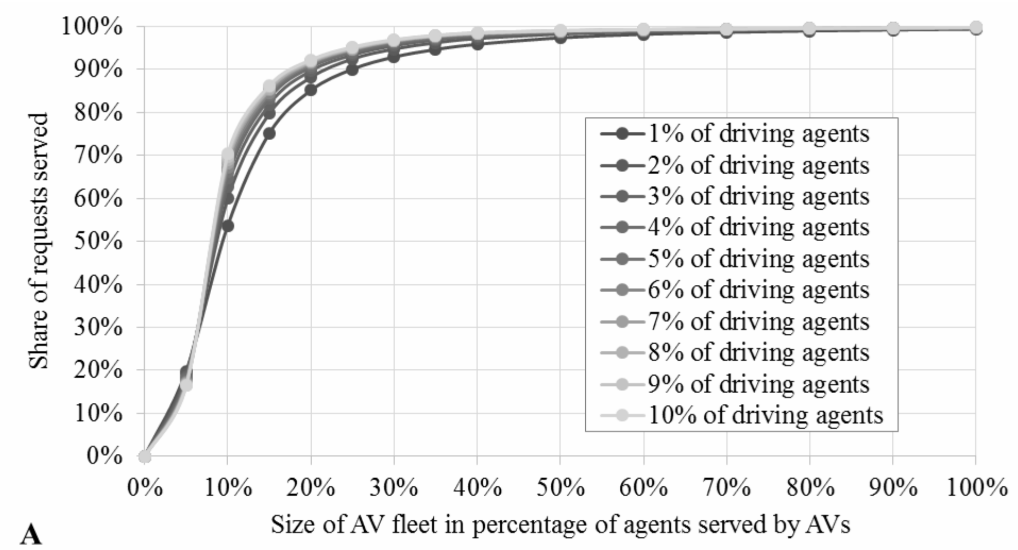
Beeline with detour factor (1.43)

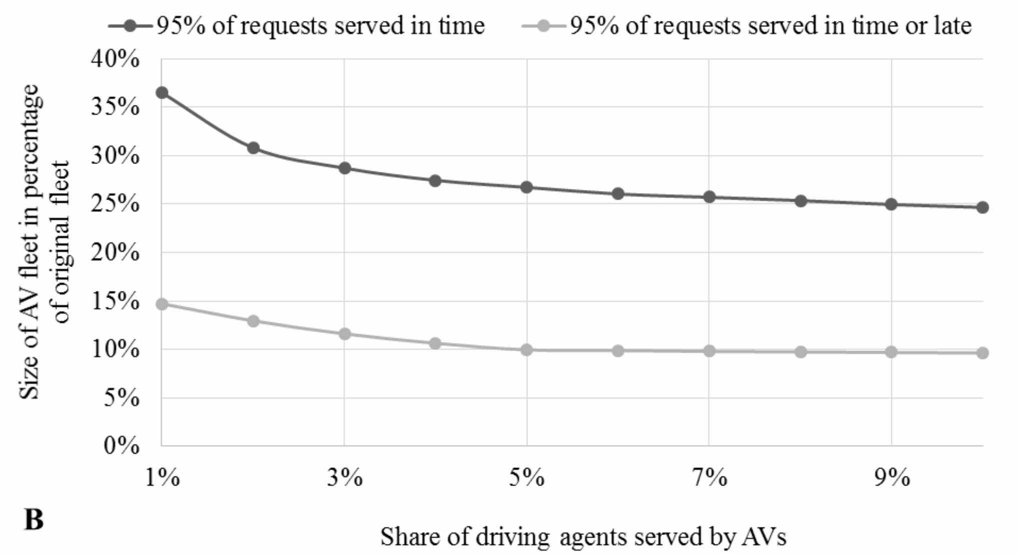
↓

Service

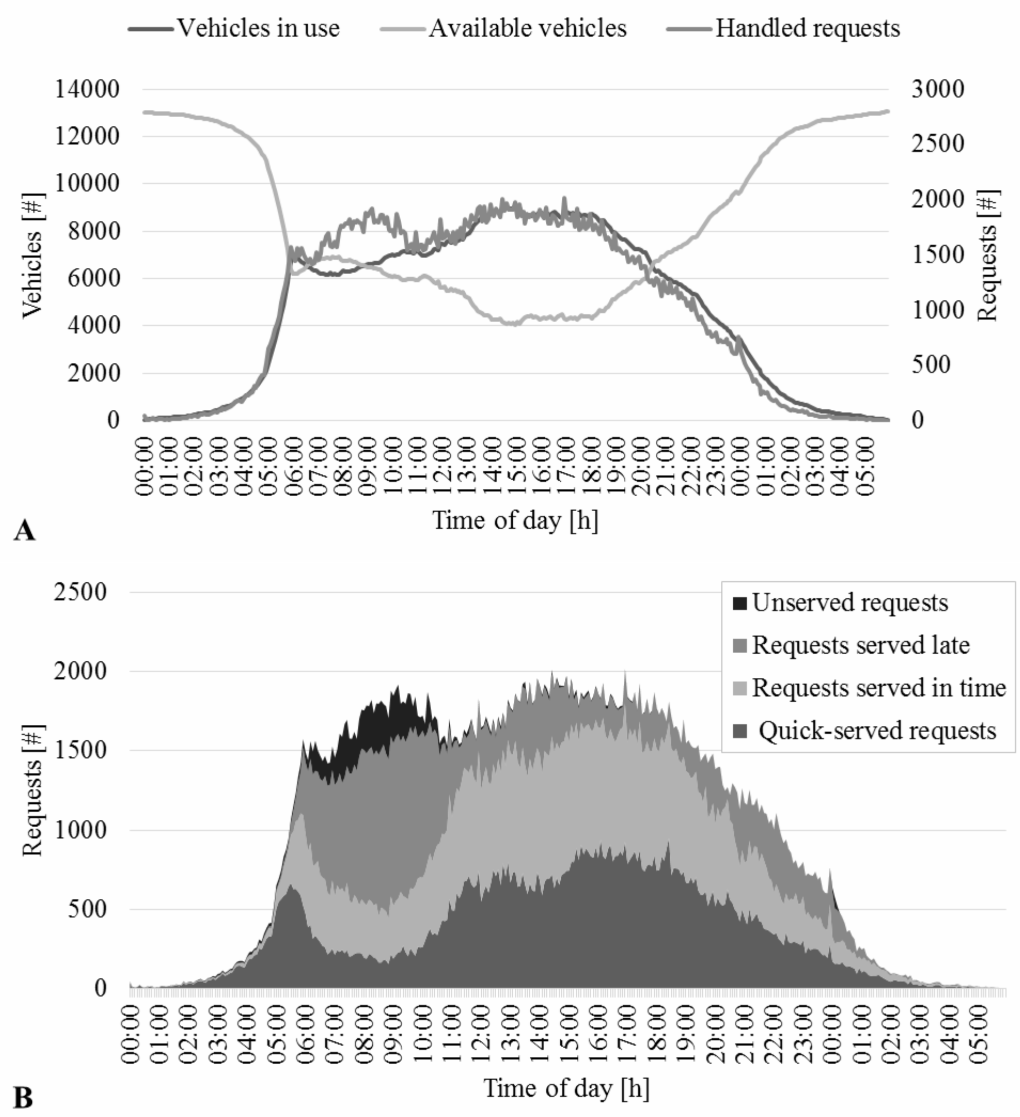
Travel time as found in MATSim

Results – Fleet Performance vs. Demand Size

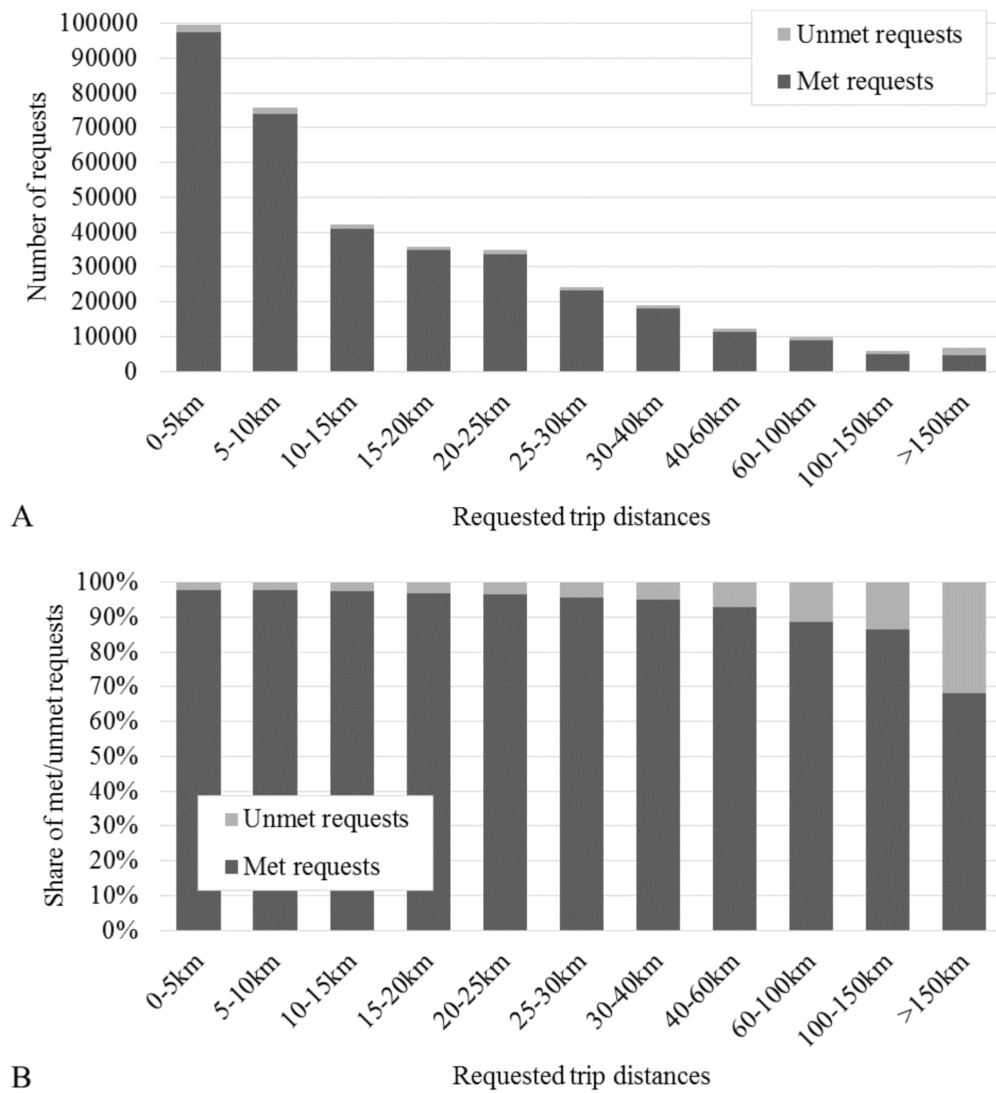




Results – Scenario 10% Demand / 10% Supply



Trip Distances



Findings

Compared to literature a **lower fleet usage**

- Large Area
- No Relocation

Fleet reduction of 90% possible

- Comparatively long reaction times AVs allowed (10 minutes)
- High density of requests close to Zurich overcompensates area effect

=> Spatial aspects of study area have strong influence

It has several limitations, the main one is that demand is static and doesn't depend on the supply