Re-defining the role of public transport in a world of Shared Autonomous Vehicles

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Introduction

Advances in automated driving may sooner or later lead to fleets of autonomous vehicles offering taxi like services. These are often referred to as Shared Autonomous Vehicles (SAVs), autonomous taxis, or robotaxis. Their possible implications on car traffic, car ownership, parking and the re-design of urban space are already in the focus of research. [1,2,3] Without the need for a driving license and low-to-zero fixed user costs and low variable user costs [4], SAVs will, however, also compete directly with classical, schedule-based public transport. At the same time, public transport systems may benefit enormously from SAVs that provide an integrated feeding services to fast rail or BRT lines. An integrated system with seamless intermodal connections between both modes may be beneficial for both pt users and operators and the future of public transport in general.

Methodology

In this study, we will use a multi-modal transport simulation model of the greater Berlin area [5] and the transport simulation software MATSim (Multi agent transport simulation) to simulate the introduction of SAVs in Berlin. The general concept of MATSim is the simulation of agents performing activities and navigating in between them using different transport modes over several iterations until some equilibrium is reached [6].

The simulation of SAVs is based on MATSim's DVRP (dynamic vehicle routing problem), taxi and AV extensions, which form a framework for dynamic transport modes [7] that have been widely used recently and allows for a state-of-the-art simulation of SAVs applications.

The standard public transport routing functionality of MATSim currently allows only the simulation of public transport trips in combination with walk trips to and from a pt stop. In a first step, this is extended to allow the simulation of intermodal trip chains, which form the fundament of a combined SAV-pt routing.

Next, an all-or-nothing approach is used where all bus and tram lines in Berlin are removed from the transit schedule and only train lines (underground and suburban) are available as forms of scheduled based public transport. In addition to that, agents may choose to take a SAV to access and egress a useful train station in their origin's or destination's vicinity (up to 5 km beeline distance), or to directly use a SAV should no useful pt route exist. This somewhat extreme scenario allows the estimation of a feasible fleet size of SAVs. In order to do so, a variable fleet size between 10,000 and 100,000 vehicles is used. The scenario is also an indicator to estimate congestion effects that may be expected especially around big stations.

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In a last step, agents have again the opportunity to choose between using pt based on a full transit schedule (including trams and busses) or choose to use the combined SAV pt mode described before for several iterations. After each tenth iteration, a certain set of the most loss making bus and tram routes are removed from the schedule. This process is repeated as long as the overall user benefits of pt users are increasing. The resulting transit schedule may then be assessed and its plausibility could be discussed.

Results

In the first step, an integration of SAVs as access and egress mode for pt trips could be achieved and is ready to use.[2]

As to the application in the Berlin scenario, we could demonstrate that a fleet of roughly 50,000 SAVs is required to replace the service currently offered by 1,500 busses and 600 trams. The average waiting time for a SAV in this scenario would in this case be less than three minutes. Further, the scenario shows that the highest number of intermodal SAV-pt connections occur in densely populated outskirts of the city and along the inner overground (*S-Bahn*) circle. This is also where most congestion occurs.[3] For passengers, there is an overall decrease in travel times, though for the majority of travelers it is lower than ten percent.

As to the last step, results are still preliminary. Yet, there is a clear tendency that heavy-duty, inner city bus lines, as well as trunk lines in the outskirts remain significant in an integrated SAV-pt scenario. Especially in outskirts, where conventional busses often only run two to three times per hour, the shift towards SAV usage for feeding can greatly decrease travel times. The economic assessment of the scenario, as well as the required fleet of SAVs, trams and busses needs yet to be undertaken.

Conclusion and discussion

The impact of Shared Autonomous Vehicles on public transport systems is still very hard to predict. The simulation based approach described in this study may help to predict a possible interaction of both modes in the future. The results suggest that schedule based services should focus on trunk routes and leave the last-mile access in less densely populated areas to SAVs.

However, the simulation described here is mainly build upon routing logic. Further research should also include a behavioral model, that with regard to SAV usage, need yet to be created. Also, a possible pooling of trips should be assessed.

[2] for the source code and a runnable example, see https://github.com/matsim-org/matsim/tree/master/contribs/av/src/main/java/org/matsim/contrib/av/intermodal

[3] congestion effects are measured based on the assumption that SAVs and conventional cars behave similar in traffic and former car users keep on using their own vehicle. Both assumptions and their implications have been addressed in science and also by the authors, but are not the focus of this study.

References

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