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Potentials of Autonomous Vehicles in a Changing Private Transportation System – a Case Study in the Stuttgart Region

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Abstract

The extensive market introduction of autonomous vehicles will be revolutionary for traditional transportation systems. Especially today's clear boundaries between private and public transportation systems will blur. Due to the possibility of an autonomous relocation of cars, car-sharing will become more relevant and compete the protected taxicab market in Germany. Private car ownership might even become redundant. Having these possible future circumstances in mind, we use a microscopic travel demand model to simulate the mode choice behaviour in a case study for the Stuttgart region: we presume a world without private cars and the presence of a large autonomous mobility on demand (AMOD) service instead. Following, under the assumption that up to four persons share a ride, we calculated the number of cars needed to run the AMOD service smoothly.
We show that not all trips, previously made by private car, are substituted by the AMOD service; the modal share of walking, public transportation and bicycling is increasing as well. Due to lower cost of the AMOD service compared with car trips, trip lengths increase as well. The results show that about 45% of all vehicle movements and 20% of all vehicle kilometres could be saved. Furthermore, the results show that about 85% of all vehicles in the Stuttgart region might be dispensable.

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Keywords: autonomous vehicle, mobility on demand, travel demand simulation, agent-based simulation

1. Introduction

The breakthrough of autonomous vehicles (AV) is no question of 'if' – it is a question of 'when'. Hence, the big research topics are the impacts of AVs on different fields of transportation e.g. on travel behavior, as well as on traffic flow assuming level 5 of automation. Autonomous vehicles have obviously advantages such as a higher safety

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level, reduced emissions due to optimized speed and car-to-car/car-to-infrastructure communication, as well as more mobility options for disabled, younger, or older people and using the riding time for other activities, e.g. working or reading. Especially in large urban areas, these advantages of AVs in addition with information and communication technologies may change transportation from private cars towards autonomous mobility on demand (AMOD) services as a new kind of public transportation. Vehicles can be used more efficiently regarding use of space and waiting times. At the same time, cost efficiency will increase since no driver is needed and the relocation of vehicles is automated as well. These advantages offer many new possibilities for carpooling in combination with AVs. In this paper, we analyze the effects of a possible AMOD service, assessing the necessary number of cars and changes in car mileages.

In this case study, we assume a future scenario with 100% AVs in a well-working AMOD system in a world without private cars. We use the travel demand model *mobiTopp* to simulate the travel demand for this scenario for the Stuttgart region with 2.3 million agents over a period of one week. Based on the O-D-demand of the model, we determine the number of AVs which would be necessary in order to cover the mobility needs of the Stuttgart population without adapting their travel.

2. Literature Review

AVs as well as mobility on demand (MOD) services have been a huge research topic within the past years as they both promise many advantages towards the usage of conventional private owned vehicles. Besides technical issues, recent work also dealt with issues in many other fields. Fagnant & Kockelman (2015) addressed policy issues discussing the impacts of AVs. They conclude that AVs have the potential to reduce crashes, ease congestion, reduce parking needs and much more. In another discussion, Boesch & Ciari (2015) state that the impact of AVs on mobility might be huge and therefore have to be modelled in a microscopic simulation framework where travelers and cars are modelled individually. Cyganski, Fraedrich, & Lenz (2015) did a qualitative research about the modal shift potential and the potential use of travel time using autonomous vehicles.

Currently, a hot topic is to investigate AMOD services. In general, four issues regarding AMOD services are addressed: the number of cars needed, relocation issues and waiting times. Bischoff & Maciejewski (2016), for example, used the agent-based simulation MATSim (Balmer, Meister, & Nagel, 2008) to simulate a city-wide replacement of private cars by autonomous taxis based on the demand of all car trips in Berlin. Martinez, Correia, & Viegas (2015) also simulated an autonomous taxi system using a self-developed platform. Shen & Lopes (2015) compare different car scheduling strategies using the Expand and Target algorithm and the simulation platform Mobility Testbed (Čertický, Jakob, Píbil, & Moler, 2014). Using the same Mobility Testbed, Čertický, Jakob, & Píbil (2015) analyzed waiting times of AMOD travelers. There are more studies targeting more or less the aforementioned issues (Shen & Lopes, 2015; Zhang & Pavone, 2016). Spieser, Treleaven, Zhang, Frazzoli, Morton, & Pavone (2014) also investigated financial benefits of AMOD systems. Fagnant & Kockelman (2014) used an agent-based approach to investigate the environmental implications of shared autonomous vehicles considering also their relocation needs. Still, none of them did consider any changes in mode and destination choice behavior.

Davidson & Spinoulas (2015) consider AVs in a macroscopic travel demand model. They analyzed different scenarios by varying the AV share, the trip increase as well as the vehicle operation cost. They showed that more trips in the future and lower costs by electric driven AVs have an impact on the modal share as well as on the trip lengths. However, they did not consider the impact of AMOD services.

To the authors' knowledge, there is no work considering both, changes in travel behavior and AMOD services. Our microscopic multi agent travel demand model *mobiTopp* is able to show changes in destination and mode choice for a simulation period of one week. With this model results, we are able to evaluate an AMOD service in the course of one week regarding changes in travel times as well as cars needed.