Autonomous car- and ride-sharing systems: A simulation-based evaluation of various supply options for different regions

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Extended Abstract

Introduction

The introduction of autonomous (or driverless) vehicles is expected in the upcoming decades. At this point, it still seems unclear on which time scale the transition is likely to happen and through which channels (i.e. private vs company-owned) these vehicles enter our roads. Privately owned autonomous vehicles may (ceteris paribus) offer a variety of improvements to users and the transport system as a whole, such as enhancements in traffic flow and emissions, safety, cost-efficiency, time-use, or accessibility (see, e.g., Gruel and Stanford, 2016; Fagnant and Kockelman, 2015; Litman, 2014; Tampère et al., 2009). For car- and ride-sharing systems, in contrast, the automation of vehicles has a disruptive potential since it possibly lifts these systems from a niche to a mainstream market, establishing a new mode of transport.

Before a new transport mode is introduced, there are several questions that need to be answered. Potential operators might ask under which conditions the service turns out to be profitable. Public authorities might wonder what impacts the new mode will have on the usage of other transport modes (in terms of shift in modal split and vehicle-kilometers traveled), how to avoid the emergence of a monopolistic provider, and whether or not to subsidize the new service in certain areas in order to provide a cost-efficient travel alternative to private cars or expensive conventional public transport.
Against this background, the present paper uses a simulation-based approach to evaluate the impacts of Autonomous Car Sharing (ACS) and Autonomous Ride Sharing (ARS) systems on the transport system in Germany.

Model

The transport simulation model consists of the first three steps of a classical four-step model (trip generation, destination choice, mode choice). For flexibility reasons, it explicitly omits the traffic assignment step and is therefore rather suited for sketch planning and first estimations. However, the travel demand is captured in great detail as the model uses all trips reported in the German national travel survey (DLR and Infas, 2008).

The autonomous sharing systems are introduced into a scenario for Germany of the year 2035, where autonomous private cars are already present in the vehicle fleet, exhibiting the reference case (Kröger et al., 2016; Trommer et al., 2016). The ACS system allows at most one party in the same vehicle at all times. The AP system allows more than one party in the same vehicle, i.e. a sharing of trips and out-of-pocket costs; however, passengers have to expect detours for picking up and dropping off others. Operator costs include the mileage-dependent depreciation of vehicles, fixed costs per vehicle per year, variable costs per vehicle (e.g. personnel costs, considering scale effects for larger fleets), and fuel costs for empty and loaded trips.

The present study puts emphasis on the analysis of two supply side parameters (user price and fleet density) and their difference for ACS and AP systems in rural, suburban, and urban regions in Germany. For this purpose, a parametric approach is used, systematically varying the supply parameters, eventually exhibiting their impact on operator profit, system travel times, or capacity utilization of the vehicles. The lower the user price, the higher the demand for the AVoD mode, but the lower also the operator revenue per kilometer. The more vehicles are offered in the system, the higher will be the demand, but the higher the operator costs for maintaining the system.

Results

The results indicate that – under the current assumptions – there are positive ACS and AP business cases even in rural areas for user prices above 0.40 EUR/km and fleet densities between one and eight vehicles per 1,000 inhabitants.

Looking at the difference between ACS and AP operations in urban areas, Fig. 1a and Fig. 1b show the operator profit as a function of user price (in EUR/km) and fleet size (in vehicles/1,000 inhabitants) for the ACS and the AP system, respectively. White areas indicate a capacity utilization of the vehicles above 0.5 (the car is on the move for more than 12 hours per day). Such scenarios do not seem operationally feasible and are therefore not considered further. Green areas indicate positive business cases, whereas orange and red areas indicate deficits for the operator. As one can observe, both systems exhibit positive business cases for price levels above 0.40 EUR/km and a fleet density below eight vehicles per 1,000 inhabitants. Because of the ride and cost
Figure 1: Operator profit per inhabitant and year as a function of user price (EUR/km) and fleet density (vehicles/1,000 inhabitants) for urban areas in Germany.

In the full paper, it is planned (i) to investigate further on the issue of the AP mode competing with traditional public transport, (ii) to present system-wide indicators such as system travel times, and (iii) to run sensitivity analyses for the profitability areas by modifying the assumptions in both, the mode choice and the operator cost model.

References


