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# Autonomous or driver-less vehicles: Implementation strategies and operational concerns

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A B S T R A C T

Autonomous vehicles are expected to shift not only the driving paradigms but also the notion of vehicle ownership. Although autonomous vehicles are believed to introduce many safety, mobility, and environmental benefits, they will be initially priced relatively highly. This paper assesses the potential for circumventing this barrier by promoting a shared ownership program in which households form clusters that share the ownership and ridership of a set of autonomous vehicles. Such a program will increase the utilization rate of vehicles, making ownership of autonomous vehicles more economical. We study parameters that affect the benefits expected from autonomous vehicles, and introduce policy directions that can boost these benefits.

## 1. Introduction

Sharing economy, also known as collaborative consumption, is a fairly old concept that focuses on the benefits obtained from sharing resources (products or services) that would otherwise go unused. Although communities have been using the concept of sharing economy locally for many years, advent of internet has led to its spread in global markets, and has highlighted its benefits.

The sharing economy model has been historically used for high-value commodities, such as exotic automobiles, yachts, private jets, vacations homes, and the like. Although it has been long realized that taking ownership of under-utilized high-value assets may not be always economically viable, this economic model has become more popular recently for less expensive resources as well, thanks to new platforms that allow easy and quick development of companion mobile applications. Sharing economy in the context of mobility should not be confused with Mobility as a Service (MaaS). While using MaaS is typically attributed to foregoing vehicle ownership altogether and outsourcing transportation as a service, shared-use mobility does not necessitate foregoing vehicle ownership and can take various forms (e.g., public transportation, ridesharing, carsharing, bikesharing), where some players may own vehicles and share vehicles/rides with others.

Autonomous (also known as driver-less and self-driving) vehicles are expected to enter the market in the near future. Although these vehicles introduce many benefits such as higher degrees of safety and mobility to the users, their high prices, primarily resultant from the added cost of different types of sensors they need to be equipped with, can be prohibitive when it comes to purchasing them (Wickerham, 2017). On the other hand, autonomous vehicles can reduce the number of vehicles a household may need to perform daily tasks, since these vehicles can drive themselves to locations where there is demand for transportation. One possible strategy to make autonomous vehicles more affordable is to encourage shared ownership of these vehicles. Moreover, it is possible to lower the ownership cost of autonomous vehicles further by (*i*) promoting shared ridership of these vehicles, and (*ii*), renting out these vehicles when they are not being used by their owners.

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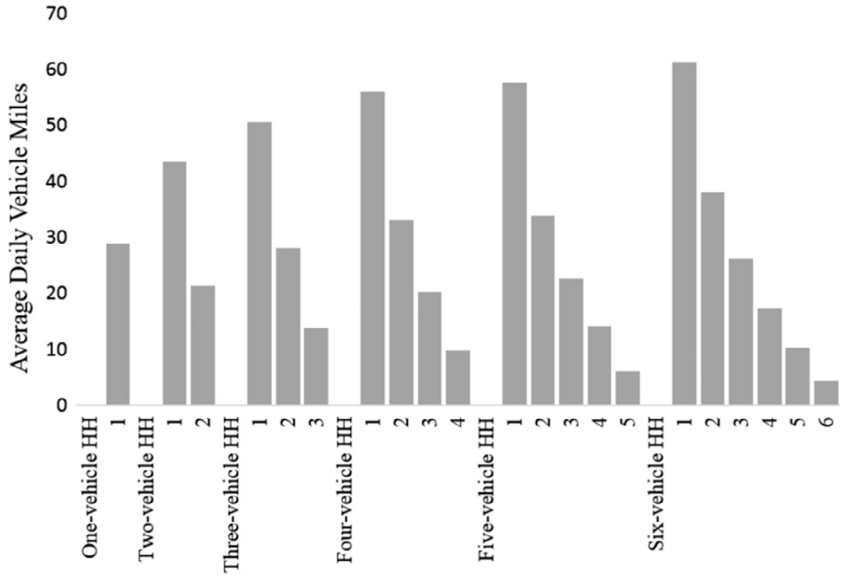


**Fig. 1.** Average daily vehicle miles for households with various number of vehicles. (Data obtained from the National Household Travel Survey (NHTS), 2009.)

The ability of autonomous vehicles to operate without a driver lowers the number of vehicles a household may require to perform its daily tasks. Fig. 1 demonstrates the average daily vehicle miles traveled (VMT) by each vehicle in a household in the US in 2009. This figure suggests that the higher the number of vehicles owned by a household, the less the average utilization rate of each additional vehicle tends to be. Although for a typical household owning more than one vehicle might be financially justifiable considering the level of comfort and peace of mind vehicle ownership may bring, this justifiability decreases with the purchase of additional vehicles. Apart from the initial investment (or monthly payments), the cost of insurance, depreciation of value, and parking can turn vehicle ownership into a financial burden. With autonomous vehicles, fewer vehicles can cover the same set of trips compared to a higher number of legacy vehicles, making the idea of each household member owning a car an obsolete one.

Though no rigorous analysis under optimal operations appear to have been done in the literature yet, there is some awareness of such possibilities in the automotive industry as well as among the increasing number of researchers and aficionados of autonomous vehicles (Schall, 2015; Naughton, 2015; Fagnant and Kockelman, 2014; Schoettle and Sivak, 2015). In this paper, we introduce the shared vehicle ownership and ridership (SVOR) program in which a group of households jointly own and use a set of autonomous vehicles. Households can share rides with each other if the spatiotemporal distributions of their trips allow for it. We propose analytical optimization schemes to study the impact of this program at both individual and system levels.

## 2. Literature review

The proposed program in this paper combines three shared mobility models: fractional vehicle ownership, and peer-to-peer car- and ride-sharing. We combine the individual advantages offered by each of these models, and propose a system that aims at maximizing efficiency.

Fractional ownership of luxury commodities emerged in the US in 1970s with real estate time shares, and was later spread to other high value commodities (Garigliano, 2007). Ford, in partnership with Zoomcar, was the first company to start a pilot project of fractional ownership of non-luxury vehicles in Bengaluru, India, as a part of its 25 mobility experiment initiative (John and Phadnis, 2015). During this three month pilot which took place in 2015, Zoomcar provided 5 vehicles, each of which were shared by 6 individuals. This was a first step for Ford and Zoomcar to study the impacts and implications of fractional vehicle ownership. Following this experiment, Ford made a "$"24M investment in Zoomcar in 2016 (Prasad, 2016).

In the proposed system in this paper, households who share the ownership of vehicles have the possibility of sharing rides, if their trips are spatiotemporally compatible. Ridesharing systems are well-studied in the literature, and a large volume of studies have confirmed their numerous benefits, including reduction in vehicle miles traveled (VMT), and less damage to the transportation infrastructure and the environment (Chan and Shaheen, 2012; Heinrich, 2010).

Literature suggests that when it comes to switching to autonomous vehicles, previous modality preferences play an important role. Individuals whose previous modality relies heavily on private vehicles are less likely to forego vehicle ownership in favor of a central shared mobility service provider (Krueger et al., 2016). Shared ownership of autonomous vehicles can provide such households with the peace of mind of vehicle ownership, while at the same time leaving the door open for shared ridership.

In order to make shared ownership of autonomous vehicles more affordable, households can rent their vehicles when they are not being used. The advantage of using autonomous vehicles in carsharing programs is that the complicated dispatching problem that one-way car sharing systems face does not arise, since autonomous vehicles can drive themselves and there is no need to plan and