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The impact of private autonomous vehicles on vehicle ownership and unoccupied VMT generation

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ABSTRACT

With 36 ventures testing autonomous vehicles (AVs) in the State of California, commercial deployment of this disruptive technology is almost around the corner (California Department of Transportation, 2016). Different business models of AVs, including Shared AVs (SAVs) and Private AVs (PAVs), will lead to significantly different changes in regional vehicle inventory and Vehicle Miles Travelled (VMT). Most prior studies have already explored the impact of SAVs on vehicle ownership and VMT generation. Limited understanding has been gained regarding vehicle ownership reduction and unoccupied VMT generation potentials in the era of PAVs. Motivated by such research gap, this study develops models to examine how much vehicle ownership reduction can be achieved once private conventional vehicles are replaced by AVs and the spatial distribution of unoccupied VMT accompanied with the vehicle reduction. The models are implemented using travel survey and synthesized trip profile from Atlanta Metropolitan Area. The results show that more than 18% of the households can reduce vehicles, while maintaining the current travel patterns. This can be translated into a 9.5% reduction in private vehicles in the study region. Meanwhile, 29.8 unoccupied VMT will be induced per day per reduced vehicles. A majority of the unoccupied VMT will be loaded on interstate highways and expressways and the largest percentage inflation in VMT will occur on minor local roads. The results can provide implications for evolving trends in household vehicles uses and the location of dedicated AV lanes in the PAV dominated future.

1. Introduction

Many vehicle manufacturers and IT companies have announced plans for deployment of autonomous vehicles by the year 2020. As of June 27th, 2017, 36 ventures have received permits to test prototypes of self-driving vehicles on road in California (California Department of Transportation, 2016). This revolutionary transportation technology will undoubtedly alter household vehicle ownership and VMT generation patterns in cities (Fagnant and Kockelman, 2015a; Litman, 2014). The impact of AV on vehicle ownership and VMT generation depends heavily on the business models of the technology, including Shared AVs (SAVs) and Private AVs (PAVs). SAV is an envisioned self-driving taxi system. The operation of the SAV system is centralized to optimize the performance of the system. In the SAV model, consumers pay for mobility service rather than the fleet. Alternatively, the PAV model echoes the current

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vehicle business model, but replacing conventional vehicles with AVs.

Most of the existing studies focused on the impacts of SAVs, which are considered as more environmentally sustainable compared with PAVs. For instance, agent-based simulation models are developed to demonstrate the affordability and feasibility of the SAV system (Burns et al., 2013; Spieser et al., 2014) and to explore the impacts of SAVs on vehicle ownership, Greenhouse Gas (GHG) emissions, traffic flow, charging stations, and parking demand (Chen et al., 2016; Fagnant and Kockelman, 2014; Greenblatt and Saxena, 2015; Zhang et al., 2015a, 2015b; Zhang and Guhathakurta, 2017). Based on author's best knowledge, to date, only one report has explored the impact of PAVs on household vehicle ownership reduction potentials, using the 2009 National Household Travel Survey (NHTS) data (Schoettle and Sivak, 2014). The study only considers time conflicts in the household AV scheduling model, while other components such as the origins and destinations of trips are not included. Additionally, the study does not provide implications for unoccupied VMT generation, as the origins and destinations of trips are not provided in NHTS data.

Despite SAVs being more heatedly discussed in the existing literature, the privately-owned AVs (PAVs) may turn out to be more preferable to consumers, based on several recent AV preference survey results. Bansal et al. (2016) conducted an opinion survey in Austin. Among the 347 respondents, only 13% indicate they may be willing to give up personal vehicles and rely exclusively on SAVs whose costs are $1/mile. Additionally, the most optimistic scenario indicates over 35% of the respondents are unlikely to participate into the SAV program, regardless the cost of the service. Another SAVs preference survey suggests that given various trip characteristics profiles, more than 70% respondents choose not to use the SAV system (Krueger et al., 2016). Another stated preference survey reveals that only 5.4% of the 1920 observations in North America are willing to rely exclusively on SAVs for commuting purposes trips and only 40.63% are willing to participate into the SAV program (even at zero membership cost) (Haboucha et al., 2017). In sum, the majority of consumers may still prefer to own a private AV in the near future. Therefore, it is critical to gain a more comprehensive understanding regarding the impact of PAV on vehicle ownership and VMT generation.

Motivated by the limited understanding of the impacts of PAV on household vehicle ownership and unoccupied VMT generation, this study designs and implements a vehicle scheduling algorithm to estimate the vehicle ownership reduction potentials and unoccupied VMT generation in the era of PAV, using the 2011 travel survey data from Atlanta Metropolitan Area. Statistical analyses are then conducted to identify critical factors (such as household travel pattern, socio-economic, demographic, and built environment characteristics) that are associated with the vehicle ownership reduction potentials. Additionally, the study also examines the temporal and spatial distributions of unoccupied VMT using the synthesized trip profiles generated by the Atlanta Activity Based Travel model.

The remainder of the article is organized as follows. The subsequent section provides a brief overview regarding the existing studies regarding the impact of AVs on vehicle ownership and VMT generation. Section Three describes the data sources and methodology used to examine vehicle ownership reduction and unoccupied VMT generation potentials under PAV business model. Section Four presents and analyzes the model results. Conclusions and future research directions are discussed in Section Five.

2. Background

With autonomous vehicles technology almost around the corner, the literature regarding the impact of AVs is proliferating. Many studies show this disruptive technology will improve travel experience by reducing crashes (Harper et al., 2016), improve fuel efficiency (Fagnant and Kockelman, 2015a; Mersky and Samaras, 2016), increase road and intersection capacity (Le Vine et al., 2015; Levin and Boyles, 2016), and provide more reliable travel time, at a cost that is significantly more affordable than current private sedans (Burns et al., 2013; Litman, 2014). However, AVs, if owned privately, instead of shared among consumers, are also expected to generate several negative externalities, such as excessive VMT generation (Zhang et al., 2015a), Greenhouse Gas (GHG) emissions, and more transportation energy consumptions (Greenblatt and Saxena, 2015), stemming primarily from changes in travel behavior. The following sections summarize the existing studies regarding how AVs (either SAV or PAV) may influence vehicle ownership and VMT generation.

Most literature has focused on how SAVs would reduce vehicle ownership, using agent-based simulation models. Results show that one SAV can replace approximately 11–14 private vehicles (i.e. approximately 90% of reduction rate), assuming consumers are willing to give up personal vehicles and rely exclusively on SAVs (Bischoff and Maciejewski, 2016; Boesch and Ciari, 2015; Fagnant et al., 2015; Fagnant and Kockelman, 2014, 2015b; Martinez et al., 2015; Rigole, 2014; Zhang and Guhathakurta, 2017). The replacement rates vary slightly based on the population and employment density in the studied region. To authors' best knowledge, only one study, to date, explored how PAVs will influence household vehicle ownership. Schoettle and Sivak (2014) found that average household vehicle ownership can be reduced by 43% from 2.1 to 1.2, once households replace conventional vehicles with AVs, using weighted National Household Travel Survey (NHTS) data. However, in this study, the minimum required vehicle is estimated based on the trip starting and ending time. The location of origin and destination is not accounted for in their analyses, as such information is not provided in the NHTS data. While, in some cases, one AV may not be sufficient to serve two non-overlapping trips if the relocation time is too long. Therefore, Schoettle and Sivak's pioneering work only provides an optimistic upper bound for potential vehicle ownership reduction rate. Almost no other study, to date, has developed a model to understand vehicle reduction potential while incorporating the spatial distributions of origins and locations into the model. Additionally, little understanding has been gained regarding what type of household (i.e. socio-demographic, economic, and travel behavior characteristics) are more likely to reduce household vehicle ownership in the era of AVs.

The vehicle automation technology will undoubtedly change Vehicle Miles Travelled (VMT) for various reasons. First, several studies suggest that VMT would increase by 10–14%, once the AVs start to serve underserved population, especially those driving capability are constrained for various reasons (Harper et al., 2016). Second, VMT may also change dramatically, given variations in