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Assessing the Long-Term Effects of Autonomous Vehicles: a speculative approach

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Abstract

In recent years, self-driving cars have generated significant attention and discussion. While it is recognized that a number of technical and legal issues need to be solved, widespread adoption of self-driving vehicles is increasingly considered to be inevitable. However, the long-term effects of this technology are rarely considered and seldom examined in the literature. Among these potential impacts are a number of direct and indirect, positive and negative outcomes, and the net effect in terms of societal benefit or harm is far from clear. In this paper, we identify the several of these outcomes, and we explore conditions in the broader transportation system under which self-driving vehicles may be either harmful or beneficial. We investigate how autonomous operation could affect the attractiveness of traveling by car, how this in turn could affect mode choice, and how changes in mode choice would affect the broader transportation system. The paper considers three speculative scenarios, defined primarily by different behavioral responses to the availability of autonomous driving. The scenarios build on an established system dynamics model that represents the major forces involved in transportation systems. A wide range of outcomes are considered, and potential policy interventions are discussed.

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Keywords: Automated Driving; Autonomous Vehicle; Self-driving Car; System Dynamics; Long-Term Effects; Benefits; Negative Outcomes; Scenario Planning

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1. Introduction

Autonomous vehicles (AVs, often refered to as "self-driving cars" or "fully automated vehicles") are widely expected to play a major role in transforming our mobility systems in coming years.[1] The expected benefits of this technology are numerous: For example, it is predicted that autonomous systems can result in far safer operation and improved efficiency of traffic flow. Furthermore, people who use these vehicles could use their commuting time much more productively and pleasantly. Also, those previously unable to drive, due to age or infirmity, could gain access to the same level of mobility as today's car drivers (Hayes, 2011, Fagnant & Kockelman, 2013, Anderson et al., 2014).

With such promises, substantial effort has been exerted analyzing the technical and institutional prerequisites to deployment of AVs. However, there has been very little formal research addressing potential system-wide and longer-term effects of AVs. Most of the attention devoted to longer-term effects has taken the form of speculative, informal discussion, usually focused on one or two issues in isolation (e.g., workforce changes, sprawl, etc.).

Our paper aims to identify some of the effects of vehicle automation at the system level. We focus in particular on those reactions that may only become apparent when the entire system is considered and longer-term, indirect effects are included. To grapple with the uncertainty inherent in this subject, we use a scenario-analysis approach, and employ structured qualitative methods to develop conceptual system dynamics models. While considering the potential benefits of AVs, we ask how behavioral changes made possible by AVs might affect traffic volume and congestion, land use, and mode choice behavior. Building on this holistic view, we suggest policy recommendations to encourage desired outcomes.

2. Related Work

Much of the material published on AVs to date—in both the academic and popular press—addresses specific issues, often in isolation. For example, many studies have examined the effects of AVs on the efficiency of traffic flow (e.g. Ioannou & Chien, 1993, Fagnant & Kockelman, 2013) or their impact on safety and car sharing (e.g., Pavone, Smith, Frazzoli, & Rus, 2012, Spieser et al., 2014). To a lesser degree, there has been some attention paid to less-quantifiable effects, such as behavioral changes, effects on attitudes about public transit, changes to land-use, and the impact on urban and regional planning (see Coughlin & Yoquinto, 2015, Brustein, 2014, Madrigal, 2012, Chin, 2014).

Most papers, however, only address one or at most a few issues in relative isolation. Reports that provide a more holistic approach are rare. Anderson et al. (2014) offer a summary of the potential benefits and perils of AVs, covering immediate effects of the technology, including safety, mobility for underserved populations, congestion and "costs" of congestion for users of AVs, energy use and pollution. This work also includes a brief discussion of potential effects on land-use, including both the dispersion of destinations due to increased willingness to travel and increases in urban density in some places due to the reduced need for parking. Fagnant & Kockelman (2013) also summarize some of the expected benefits of AVs, including safety improvements, which they suggest could offer reductions in fatality rates of up to 99%, and improvements in congestion, due to "shorter headways, coordinated platoons, and more efficient route choices."

Using analytical and simulation models, Burns, Jordan, & Scarborough (2013) explore a "new mobility system" based on shared, driverless vehicles. The report finds significant economic, environmental, and consumer benefits, suggesting that such an approach could "provide better mobility experiences at radically lower cost." In similar vein, Spieser et al. (2014) and Fagnant & Kockelman (2014) show in two case studies that a shared-vehicle mobility system can satisfy the mobility demand of a city with significantly less vehicles while causing more travel for rebalancing the fleet.

Townsend (2014) and Milakis et al. (2015) use scenario-approaches to examine the implications of AVs. Milakis et al. focus more on the traffic and transportation planning implications of AVs. Their scenarios are defined along the dimensions of technological development and policies. Townsend draws four scenarios, considering different forces shaping the adoption of AVs, the resulting impacts on land use and transportation, financing schemes, and the role of planning. The vastly different outcomes of these scenarios highlight how little is actually known about how AVs will be used and how they will affect the overall system.

Research on the longer-term effects of AVs can be broken into two key categories. On the one hand side, there are rigorous analyses based on narrow sets of data. Those typically result in well-supported outcomes, but the results are