Literature Search 622: Understanding the impact of partially autonomous vehicles on Minnesota roads
June 26, 2020; updated July 7, 2020 to remove international studies

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Resources searched: TRID (includes RiP); SAE, Google Scholar

Summary: Results are organized into In Progress Research and Completed Research.

Results

In Progress Research

Project Title: Assessment of Capacity Changes Due to Automated Vehicles on Freeway Corridors
Source: Virginia Transportation Research Council (start: 2018-03-23; end 2020-05-31)
Project Summary: This project will assess capacity changes due to the introduction of connected and automated vehicles (CAVs) on Virginia freeway corridors. The AV technology considered consists of adaptive cruise control (ACC) and cooperative adaptive cruise control (CACC) with varying operational parameters. Overall three vehicle types including legacy vehicles, vehicles equipped with ACC and vehicles equipped with CACC are considered in mixed traffic scenarios to determine their overall effect on capacity. The primary focus will be on modeling basic freeway facilities at various market penetration levels to capture the effects of capacity among other measures of effectiveness for mixed traffic flows. Mixed traffic scenarios include light duty passenger vehicles and heavy vehicles each with ACC and CACC capabilities. Some limited modeling of interchanges will also occur so as to better understand the interaction between system components. The results of the project will provide Virginia Department of Transportation (VDOT) with estimates of potential freeway capacities.
Project page: https://trid.trb.org/View/1505971

Project Title: Modeling stochastic human-driver car following behavior in oscillatory traffic conditions
Source: Center for Transportation Studies, University of Minnesota (Active)
Project Summary: To calibrate stochastic ordinary differential equations for car following behavior, we will use existing vehicle-level trajectory data to calibrate models that are able to describe the stochastic nature of human driving. These models will be calibrated using different criteria such as mean squared error in speed, spacing, and headway as the objective function in a gradient-based method. This will allow for different parameter optimization techniques to be compared. The resulting models will then be compared with traffic flow simulations where some of the vehicles in the flow are replaced with autonomous vehicles. This will provide insight into how we can expect traffic flow to change in the future when autonomous vehicles are present.
Project page: http://www.cts.umn.edu/Research/ProjectDetail.html?id=2020047
**Completed Research**

Title: Travel Behavior Changes Among Users of Partially Automated Vehicles  
Source: University of California Davis, Institute of Transportation Studies (May 2020)  
Abstract: Estimates indicate that as of the end of 2019, there were over 700,000 Partially Automated Tesla Vehicles—the subject of this study—on the roads globally. Despite this, little research has been done to understand how they may be changing travel behavior. In this study, qualitative interviews with 36 users of Tesla BEVs with Autopilot were conducted. The goal of this was to understand how Autopilot is used, user experiences of the system, and whether the system has any impact on drivers’ travel behavior. The focus of the last of these aims was to determine whether Autopilot could cause or was causing an increase in vehicle miles traveled (VMT) among the study participants. Results from the interviews showed that partial automation leads to consumers travelling by car more and being more willing to drive in congested traffic. These changes are due to increased comfort, reduced stress, and increased relaxation due to the partial automation system, and because of the lower running costs of a BEV. The results also point to a need for further research of partially automated vehicles that are already on the market, as 11 of 17 reasons for increased VMT that have been identified in modeling studies of fully automated vehicles (not yet commercially available) applied to users of Autopilot.  
Full text: [https://escholarship.org/uc/item/8p0351m1](https://escholarship.org/uc/item/8p0351m1)

Title: A First Look at Vehicle Miles Travelled in Partially-Automated Vehicles (Working Paper)  
Source: University of California Davis, Institute of Transportation Studies (2018)  
Abstract: This paper contributes to research investigating the impact of automated and partially automated vehicles on travel behavior. This contribution comes from taking a first look at the impact of partially/semi-automated (SAE Level 2) vehicles on travel behavior and potential correlations with vehicle miles travelled (VMT). The results of this study are taken from a questionnaire survey of 3,001 plug-in electric (PEV) owners in the USA, of which 347 own a partially-automated vehicle (e.g Tesla Model S with Autopilot). This study looks at the VMT of different vehicle types in the survey including plug-in hybrids (PHEVs), battery electric vehicles (BEVs), and semi-automated BEVs. This comparison reveals that semi-automated BEVs have significantly higher VMT compared to other vehicle types. Least squares regression is used to understand VMT in semi-automated BEVs further. This reveals a significant relationship between commute distance, age, household income, house type, and the frequency of autopilot use, and annual VMT. It is possible that the results are showing a self-selection causality as owners of these vehicles already drove more prior to them selecting a semi-automated BEV. Nevertheless, this model indicates that as the frequency of autopilot use increases, so does annual VMT. Due to the potential for two ways causality this study cannot determine whether there is a causal relationship between the use of semi-automated vehicle technology and additional VMT. It is hoped that this first look at the impact of partially-automated BEVs will encourage more research and debate in this area with the aim of improving policy responses to partially and fully automated vehicles.  
Full text: [https://escholarship.org/uc/item/6kt1j7gj](https://escholarship.org/uc/item/6kt1j7gj)  
See also journal article published in 2019: [https://doi.org/10.1016/j.tra.2019.08.008](https://doi.org/10.1016/j.tra.2019.08.008)

Title: Impact of Connected and Automated Vehicles (CAVs) on Freeway Capacity  
Source: Center for Advanced Multimodal Mobility Solutions and Education, University of North Carolina (Sept. 2019)  
Abstract: As CAVs start to penetrate into the market, the current Highway Capacity Manual (HCM) methods cannot be used to evaluate freeway capacity due to the fact that they did not account for the impacts of CAV strategies in the HCM. To quantify the impact of CAVs on freeway capacity, new guidelines should be established in order to be suitable for use in conducting various types of analyses involving CAV strategies. The impact of different CAV penetration rates in the highway system on various facilities under different scenarios should be examined. In order to be better prepared for both CAV planning and operations under varying levels of market penetration and traffic demand, there is a critical need to develop and establish the HCM capacity adjustments. This research will develop guidelines for and make recommendations on estimating and predicting freeway capacity in the presence of CAVs or AVs, and therefore will lead
to a better understanding of how CAVs or AVs improve mobility in the freeway system. In the case study conducted in this research, four different freeway scenarios are chosen from the Caltrans Performance Measurement System (PeMS). To obtain valid results, various driving behavior parameters are calibrated to the real traffic conditions for human-driven vehicles by using VISSIM, a commonly used traffic microsimulation tool. In particular, the calibration is conducted using genetic algorithm for driving behavior parameters such as standstill distance and minimum headway between vehicles. After the calibration process, the simulation is conducted on basic freeway segments in the mixed traffic environment including regular human-driven vehicles, AVs, and CAVs. Simulation results are discussed in detail. Overall, the results of this study can help traffic engineers and stakeholders better understand how different market penetration levels of CAV and AV influence freeway capacity and therefore can help improve freeway traffic management.


Title: The Effects of Varying Penetration Rates of L4-L5 Autonomous Vehicles on Fuel Efficiency and Mobility of Traffic Networks
Source: SAE (April 2020)
Abstract: With the current drive of automotive and technology companies towards producing vehicles with higher levels of autonomy, it is inevitable that there will be an increasing number of SAE level L4-L5 autonomous vehicles (AVs) on roadways in the near future. Microscopic traffic simulators that simulate realistic traffic flow are crucial in studying, understanding and evaluating the fuel usage and mobility effects of having a higher number of autonomous vehicles (AVs) in traffic under realistic mixed traffic conditions including both autonomous and non-autonomous vehicles. In this paper, L4-L5 AVs with varying penetration rates in total traffic flow were simulated using the microscopic traffic simulator Vissim on urban, mixed and freeway roadways. The roadways used in these simulations were replicas of real roadways in and around Columbus, Ohio, including an AV shuttle routes in operation. The road-specific information regarding each roadway, such as the number of traffic lights and positions, number of STOP signs and positions, and speed limits, were gathered using OpenStreetMap with SUMO. In simulating L4-L5 AVs, the All-Knowing CoEXist AV and a vehicle with Wiedemann 74 driver were taken to represent AV and non-AV driving, respectively. Then, the driving behaviors, such as headway time and car following, desired acceleration and deceleration profiles of AVs, and the non-AVs’ car following and lane change models were modified. The effect of having varying penetration rates of L4-L5 AVs were then evaluated using criteria such as average fuel consumption, existence of queues and their average/maximum length, total number of vehicles in the simulation, average delay experience by all vehicles, total number of stops experienced by all vehicles, and total emission of CO, NOx and volatile organic compounds (VOC) from the vehicles in the simulation. The results show that while increasing penetration rates of L4-L5 AVs generally improve overall fuel efficiency and mobility of the traffic network, there were also cases when the opposite trend was observed.

Full text available upon request: https://doi.org/10.4271/2020-01-0137

Title: Modeling heterogeneous traffic with cooperative adaptive cruise control vehicles: A first-order macroscopic perspective
Source: Transportation Planning and Technology, vol. 43, no. 2 (2020)
Abstract: This paper proposes a modeling framework to characterize steady-state traffic flow relations for heterogeneous traffic composed of both standard (S) and Cooperative Adaptive Cruise Control (CACC, labeled C here) vehicles, capturing the impact of C market penetration and vehicle sequence within a lane. The resulting parameterized fundamental diagram is then integrated with a first-order macroscopic traffic model, allowing the authors to characterize the operational performance on a network for heterogeneous traffic with varying C market penetration rates. This approach is demonstrated through an illustrative case study which considers a small freeway section with time-varying demand, merging traffic from an entrance ramp, and C market penetration ranging from 0.0–1.0. The results indicate that maximum throughput does not change appreciably as C traffic is first introduced, but eventually increases significantly for mid-to-high C penetration rates. Additionally, it shows that increasing C market penetration and separating vehicle classes slows upstream congestion propagation.

Full text available upon request: https://doi.org/10.1080/03081060.2020.1717127
Title: Characterizing the impact of production adaptive cruise control on traffic flow: an investigation
Source: Transportmetrica B: Transport Dynamics, vol. 7, no. 1 (December 2019)
Abstract: This research conducted a comprehensive study to better estimate the impact of production Adaptive Cruise Control (ACC) on uninterrupted flow facilities using the highly cited ACC car-following models in the literature. Four different car-following models were investigated, including the Autonomous Adaptive Cruise Control (AACC) model, Intelligent Driver Model (IDM), California Partners for Advanced Transit and Highways (PATH) empirical ACC model, and the Technical University of Delft empirical ACC model. Each of the four models were recalibrated using data collected by a 2013 Cadillac SRX with production ACC engaged while following a human-driven 2013 Cadillac SRX in northern Virginia. Off-the-shelf commercial microscopic simulation software VISSIM was utilized to simulate the ACC traffic flow. Sensitivity analysis was conducted on ACC market penetration and following headway. Capacity and fundamental diagrams were used to quantify the impact of the ACC on traffic flow. Results indicate that freeway capacity highly depends on the market penetration of ACC vehicles. Small number of ACC vehicles (<25%) is beneficial to roadway capacity, while wider deployment of ACC vehicles (>75%) significantly harms capacity. The results strongly suggest the urgent need for vehicle connectivity.
Full text available upon request: https://doi.org/10.1080/21680566.2018.1540951

Title: Managing partially automated network traffic flow: Efficiency vs. stability
Abstract: This paper analyzes how a central agent may bring a mixed traffic system including both human-driven and autonomous vehicles to an equilibrium that both maximizes the efficiency and is stable under the control. The evolution of the human drivers’ route choices, as well as the agent’s control measures, is described using a joint day-to-day (DTD) dynamical model based on probability route choice. Within this setting, the authors show that (1) the fixed point of the proposed dynamical system coincides with the unique mixed equilibrium, and (2) the system is asymptotically stable in continuous time, namely it always converges to the mixed equilibrium from a given initial state. The authors then examine how alternative control policies may affect the transition trajectory leading to the mixed equilibrium. Two alternative control schemes are proposed and analyzed. The first, referred to as the stability-first control, aims to stabilize a given disequilibrium as soon as possible. The second seeks to minimize the total system cost accumulated over the transition period, hence called the efficiency-first control. The authors propose a continuous time optimal control formulation for both schemes and discuss how the formulation can be discretized and solved to local optimality using existing algorithms. Numerical experiments conducted on two illustrative examples highlight the differences among the three control schemes and how the share of autonomous vehicles affects the tradeoff between the efficiency and stability of the mixed traffic system.
Full text available upon request: https://doi.org/10.1016/j.trb.2018.06.004