0-6847: An Assessment of Autonomous Vehicles: Traffic Impacts and Infrastructure Needs

Background

This project investigated how connected and (fully) automated vehicles (CAVs) can affect traffic congestion and travel demand, and developed best-practice recommendations for TxDOT to support CAV adoption and system management through optimal policies and investments. Advances in vehicle communications and automation can reduce travel times and traffic crashes. CAVs offer a relatively low-cost option to increase the capacity of existing rights-of-way, but such improvements require supporting practices.

What the Researchers Did

Automobile enterprises, researchers, and policymakers are interested in anticipating CAV adoption rates over time. This work forecast Americans' long-term (2015 to 2045) adoption levels of CAV technologies under eight different scenarios based on 5% and 10% annual drops in technology prices; 0%, 5%, and 10% annual increments in owners' willingness to pay (WTP); and changes in government regulations (e.g., mandatory adoption of connectivity on new vehicles). This simulation was calibrated using data from 2,167 Americans, in order to obtain their preferences for CAV technologies (e.g., WTP) and their household's annual vehicle transaction decisions.

The researchers constructed macroscopic and mesoscopic traffic models of some of Texas' most congested locations, including Austin's downtown network. A novel reaction time-based flow-density relationship was used to predict how capacity improvements change with the space-time specific market penetration (MP) of CAVs. They also developed a mesoscopic simulation model and optimization framework for reservation-based intersection control, an efficient alternative to traffic signals.

Finally, the team created a congestion-aware agent-based model of shared autonomous vehicles (SAVs), which act like a low-cost taxi service; and a four-step planning model to incorporate empty repositioning trips, in which travelers instruct their AV to drop them off then travel home, empty, to avoid parking costs.

What They Found

Long-term fleet evolution suggests that the privately held light-duty vehicle fleet will have 24.8% Level 4 AV penetration by 2045, assuming an annual 5% price drop and constant WTP values (from 2015 forward). This share jumps to 87.2% if assuming a 10% annual rate of decline in prices and a 10% annual rise in WTP values. Overall, simulations suggest that, without a rise in most people's WTP, or policies that promote or even require technologies, or unusually rapid

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reductions in technology costs, it is unlikely that the U.S. light-duty vehicle fleet's technology mix will be anywhere near homogeneous by the year 2045.

Mesoscopic simulation results found that shorter headways between vehicles reduced travel times (and increased ramp and intersection capacities) by up to 50% on freeway, arterial, and city networks. Small benefits were observed at low MPs of CAVs, and these scaled with the proportion of CAVs. These results indicate that safe methods for reducing following headways should be encouraged by supportive policies.

Results from reservation-based intersection controls were more mixed. Although reservations have the potential to reduce delays beyond optimized traffic signals, the performance of reservations depends on the priority policy used. First-come-first-served policies do not work well in instances of significant cross traffic, when clustering of vehicles is more useful. However, reservations typically require very high (80% or more) MP; so, by the time reservations are feasible, more optimal reservation policies should be available and may be the future of intersection control after most vehicles are autonomous.

The team's travel demand model results suggest that traveler behaviors will change significantly once AVs are available. Over 60% of CAV owners prefer empty repositioning to parking on site, in order to avoid parking costs. However, empty repositioning adds empty-VMT (vehicle miles traveled) to the network and makes transit use less attractive. Consequently, TxDOT and cities and counties should consider prohibitions on all empty-vehicle travel, unless it is by an operator-managed fleet that is held to a maximum share of VMT driven empty (e.g., 10 percent, with fines for additional empty driving) and time- and location-dependent (congestion-based) road pricing should be adopted (using the GPS and DSRC that connected vehicles require).

SAVs enable rather dramatic changes in vehicle ownership and travel patterns. They can add large numbers of empty, but relatively short, repositioning trips to reach the next travelers. With transportation network companies, such as Uber, moving towards early adoption of SAV-like services, TxDOT may benefit from evaluating policies regarding SAV travel to ensure that widespread use does not result in heavy traffic congestion. Dynamic ride-sharing (sharing rides with arbitrary travelers, similar to SuperShuttle) offers cost and congestion benefits. Therefore, careful use of SAVs could provide an alternative travel mode, although TxDOT should carefully study SAVs and their effects on traffic congestion.

What This Means

With partially automated vehicles (i.e., the Tesla Model S) already available to consumers, the transition to CAVs has begun. CAVs can bring many benefits to travelers and communities via relatively minor transportation-infrastructure changes. Demand-management policies will be key, and TxDOT and other agencies will want to evaluate policies and infrastructure development to make optimal use of CAV technologies.

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