CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

0-7033: Defining Operational Design Domains (ODDs) for the Safe Blending of Levels 0-4 Connected and Autonomous Vehicles (CAVs) in the Traffic Streams

Background

Automated vehicles (AVs) present significant potential to improve roadway safety; their technological maturity and performance, however, remain to be proven. As a leader in AV deployment, Texas has a keen interest in safely advancing AV technology. With several deployments already underway, it is critical for the Texas Department of Transportation (TxDOT) to provide the public with the assurance that AVs are performing safely in their intended operational environment—the operational design domain (ODD). There is, however, no consensus on how AV safety should be evaluated, which performance metrics to use, who should oversee the process, or even a common language to facilitate public-private dialogue.

What the Researchers Did

The University of Texas at Austin Center for Transportation Research (CTR) partnered with the Mobility Systems Lab to address these research gaps. The project's purpose is threefold: define the ODD framework to describe the operational environment of an AV, evaluate AV performance by simulating AV operations in multiple scenarios, and formulate policy, technical, and research recommendations for Texas.

First, the research team conducted a literature review and engaged a broad network of stakeholders to assist with formulating a safety assessment process that is business-friendly and ensures public safety. Stakeholder feedback revealed advantages and disadvantages to the current voluntary safety self-assessment process and informed policy guidance for Texas in the next phase.

The research team defined a common ODD framework for Texas, highlighting the elements and parameters of greatest relevance to TxDOT. The research team identified several roadway environments with early deployments and ten problematic environments for special consideration. Based on input from a network of stakeholders, the research team selected five scenarios for testing and simulation.

The research team developed the scenarios by creating virtual highway and urban environments, programming the automated vehicles, and configuring the scenarios to compare automated vehicles to human driving behavior. The research team recruited 27 participants to test the scenarios in automated and manual driving modes in weaving and forced merge scenarios. Having developed a performance metric framework, the research team analyzed the safety, mobility, and human-factors results from each of the test participants to draw conclusions.

Finally, the research team synthesized the information and formulated technical, policy, and research recommendations, which enable TxDOT to improve infrastructure readiness and inform forward thinking policies.

What They Found

The results showed that, on average, the human participants were safe, but the automated driving system (ADS) was safer in every performance metric.

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Beginning with the time-to-collision (TTC), human participants drove more aggressively than the ADS as evidenced by their lower TTC values. Overall, the adaptive cruise control (ACC) feature was successful in increasing the TTC and safety in most scenarios.

The headways match this pattern and represent the distance between the test vehicle and the vehicle in front of it. Focusing on the change in level of service (LOS), the human driver and ADS headways decreased consistently with the traffic flow, increasing from LOS A to LOS D. That is, the human participants decreased their following distance by 7-12 meters on the highway and 6-10 meters in the urban downtown when entering the LOS D conditions; similarly, the ADS decreased its following distance by 11-12 meters on the highway and 8-9 meters in the urban downtown upon entering LOS D. The ACC feature is effective in maintaining a consistent following distance, thereby increasing the headway, time-to-collision, and occupant safety.

The lateral offset is key to determining the distance that a vehicle swerves from the lane's centerline. Human participants across all scenarios deviated an average of 0.4 meters and a maximum of 2.0 meters, which is half of the lane width. The human drivers regularly crossed lane boundaries, while the ADS maintained its position within the lane and was consistently centered—displaying an average lateral offset of 0.04 meters and a maximum lateral offset of 0.25 meters. The lane centering feature therefore proves valuable in reducing lateral collision risks.

The ADS also demonstrated significant benefits in optimizing traffic flow over the human drivers. When comparing the velocity profiles, the ADS produced a significantly smoother experience than a human driver, which is attributed to its advanced sensing and control algorithms. Therefore, AVs have the potential to reduce congestion and emissions across the transportation network.

Finally, the research team developed a prototype takeover alert system in order to test driver reaction time to resume control of the AV. While the participants were able to regain control in under 2.0 seconds, further research is needed to study the risks of automation complacency

What This Means

The ODD project results have implications for future research and legislation on AV technology. Texas has created an attractive market with its business-friendly regulatory environment. Historically, the Texas legislature has sought to offer clarity and remove regulatory barriers when identified, making Texas a leader in the deployment of AV technologies. In alignment with this approach, the research team focused on key areas to assist TxDOT in its guidance to the Texas legislature, including terminology, policy best practices, and safety standards. In addition to policy recommendations, the research team has identified several technical recommendations. These recommendations come from the experimental results and highlight areas for further research, advancements for safety, and connections between policy and technology

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