Automated Driving System-Work Zones Technical Peer Exchange

February 20, 2024

U.S. Department of Transportation

HASS

Highly Automated Systems Safety Center of Excellence

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Executive Summary

The Automated Driving Systems (ADS) Demonstration Grants Program appropriated funding to a collection of highly automated vehicle research and development projects testing the safe integration of ADS into our Nation's on-road transportation system. The program includes two Federal Highway Administration (FHWA)-managed projects that have performed research on how ADS-equipped vehicles can interact safely in challenging dynamic scenarios, particularly work zones. Two ADS Demonstration grant projects currently working on such demonstrations are led by the Virginia Tech Transportation Institute (VTTI) and the Pennsylvania Department of Transportation (PennDOT). Several other states are also allowing ADS testing on public roads and have gained valuable experience and lessons learned from their testing.

The U.S. Department of Transportation (U.S. DOT) Highly Automated Systems Safety Center of Excellence (HASS COE) team recently received a request from the PennDOT ADS Demonstration grantee to host a technical peer exchange as they prepare for live on-road testing of ADS-equipped vehicles with a safety driver. The PennDOT team has done extensive simulation and closed track testing of ADS vehicles across 16 work zone scenarios and is currently preparing for live on-road testing in three work zone settings: conventional roadway, freeway, and mobile work zone. The team has identified several key areas of consideration to ensure the success of their on-road testing of ADS vehicles.

Recognizing that the topic of safe demonstration of ADS technologies on public roads in work zones may be valuable to all ADS Demonstration grantees and other major stakeholders, the HASS COE team facilitated an information exchange session on February 20, 2024. The technical peer exchange, which focused on automated vehicle (AV)/ADS testing and deployment in live work zone operations, invited ADS Demo grantees as well as relevant state, local, and other deployers to offer insight, guidance, consideration, and lessons learned for operating in work zones.

This paper summarizes the notes from the technical peer exchange on AV/ADS testing and deployment in work zones. The paper also references several resource materials around this topic that were previously recommended by our U.S. DOT colleagues.

Attendees

Ahmad, Omar (University of Iowa)

Averkamp, Austin (Transurban)

Berg, Ian (U.S. Department of Transportation Volpe Center)

Brennan, Sean N (Pennsylvania State University)

Burgos-Gomez, Ed (Federal Highway Administration)

Burt, Matthew (U.S. Department of Transportation Volpe Center)

Calvillo, Alex (Ohio Department of Transportation)

Castignoli, Rachel (City of Austin)

Corbin, John (Federal Highway Administration)

Deshmukh-Towery, Nate (U.S. Department of Transportation Volpe Center)

Durant, Brynn (Ohio Department of Transportation)

Engle, Jeff (Federal Highway Administration)

Every, Joshua (U.S. Department of Transportation Highly Automated Systems Safety Center of Excellence)

Fisher, Thomas (Federal Highway Administration)

Geara, Tony (City of Detroit)

Grate, Daniel (Federal Highway Administration)

Hall, Tiffany (Federal Highway Administration)

Herrmann, Derrick (Pennsylvania Department of Transportation)

Houpt, William (Federal Highway Administration)

JonMichael, Jason (U.S. Department of Transportation Highly Automated Systems Safety Center of Excellence)

Kapitanov, Martha (Federal Highway Administration)

Khan, Mubassira (U.S. Department of Transportation Highly Automated Systems Safety Center of Excellence)

Knickerbocker, Skylar (Iowa State University)

Krum, Andrew (Virginia Tech Transportation Institute)

Langari, Reza (Texas A&M University)

Loftus, Jeff (Federal Motor Carrier Safety Administration)

Mockett, Mark (U.S. Department of Transportation Volpe Center)

Mollenhauer, Mike (Virginia Tech Transportation Institute)

Mortensen, Steven (Federal Transit Administration)

Nylen, Ashley (U.S. Department of Transportation Highly Automated Systems Safety Center of Excellence)

Ocel, Norah (Federal Highway Administration)

Olds, Tara (Minnesota Department of Transportation)

Peterson, Todd (Federal Highway Administration)

Petz, Konner (City of Detroit)

Ponnaluri, Raj (Florida Department of Transportation)

Raamot, Eric (U.S. Department of Transportation Highly Automated Systems Safety Center of Excellence)

Rajkumar, Raj (Carnegie Mellon University)

Rhone, Gunnar (Pennsylvania Department of Transportation)

Schwerdt, Tom (Texas Department of Transportation)

Thomas, Duane (Federal Highway Administration)

Trudelle, Jami (Federal Highway Administration)

Varadarajan, Vijay (HNTB)

White, Barry (Ohio Department of Transportation)

Williams, Ben (Federal Highway Administration)

Wallace, Andrew (Ohio Department of Transportation)

Zhang, Kevin (U.S. Department of Transportation Volpe Center)

Background

Ashley Nylen, HASS COE Acting Assistant Director of Program Development & Strategy, and Mubassira Khan, HASS COE Senior Scientist, introduced the purpose of the ADS-work zones technical peer exchange to allow ADS Demonstration grantees and other State and local partners with ADS testing experience to share considerations, lessons learned, and best practices for testing ADS and automation in live work zones.

Gunnar Rhone (PennDOT) noted that this meeting was requested through Jeff Engle (FHWA Pennsylvania Division), who had learned of some of the challenges facing the PennDOT team during their development of live work zone environment testing scenarios.

Discussion

The ADS-work zones technical peer exchange discussion explored six key topics: site control; pavement marking considerations; site setup; State and local standards, specifications, or other general requirements; insurance requirements; and State, local, and deployer experiences with ADS operation.

Topic 1: Site Control

Gunnar Rhone (PennDOT) introduced the first topic of discussion, *site control*. Rhone asked how site control has been achieved by other projects and what types of training have been made available to the project team and/or contractors. A summary of the discussion is provided below:

- Mike Mollenhauer (VTTI) responded that, with respect to training, the contractors involved received training for both their ADS demonstration and automated truck-mounted attenuator (ATMA) projects. The trainings covered potential safety issues, functional elements (e.g., the location of emergency stops), and other human-machine interfaces. The trainings were approximately 90 minutes in length, and were delivered to managers, work crews, and other operational staff. In addition, a safety briefing was held at the beginning of each day before going into the field. Mike also noted that a safety driver was present during their testing.

Topic 2: Pavement Marking Considerations

Raj Ponnaluri (Florida Department of Transportation [FDOT]) introduced the second topic of discussion, *pavement marking considerations*. A summary of the discussion is provided below:

- FDOT informed the group of their findings from conversations with companies focused on pavement markings via a Request for Information in December 2023, which received three respondents:
    - There is not a decisive, quantitative way to classify pavement markings, and they are typically sorted into low, medium, and high qualitative categories.
    - Many efforts appear to rely on video feeds to detect and classify pavement marking presence and quality.
    - Other efforts are evaluating the use of photogrammetry and satellite imagery.
- FDOT noted the value of engaging in future conversations with original equipment manufacturers (OEMs) to further understand the application of machine learning to reading roadway markings and how pavement contrast plays a role.
- Sean Brennan (Pennsylvania State University [PSU]) described his work measuring LiDAR and camera behavior with respect to pavement markings and expressed interest in further discussions with FDOT, particularly on the topic of incorrect markings (e.g., cases where documentation indicates a road

marking should have glass beads, but the glass beads were omitted from readings).

Topic 3: Site Setup

Sean Brennan (PSU) introduced the third topic of discussion, *site setup*. Building on the topic of site control, Sean asked whether there were any specific requirements other deployers have implemented in terms of wearables that the work zone workers or anyone in the work zone used, and if there were legal or insurance needs related to testing within the work zone environment. A summary of the discussion is provided below:

- The VTTI team stated that their I-395 demonstration was set up as a temporary traffic incident with a path of cones to navigate around. The flagging operator wore VTTI's in-house-developed smart vest that communicated with a base station mounted on a work vehicle, transmitting an SAE J2735 Personal Safety Message (PSM) identifying the wearer as a flagger. The ADS subsequently used that information to localize the individual performing traffic control and to read the sign that the flagger was holding. Due to varying levels of accuracy in detecting the flagger's sign, the team added an inertial measurement unit (IMU) to the sign pole, trained the ADS to distinguish between "slow" and "stop" directions, and packaged that data with the message that was sent out.

- The PSU team noted that, particularly during nighttime and adverse weather conditions, the PennDOT team has not been able to rely on signage into and outside of the work zone, and they have relied more heavily on their high-definition map and Cellular-Vehicle-to-Everything (C-V2X) devices.

- The VTTI team added that they noticed different lighting conditions and times of day make a difference, and they used a VTTI-developed work zone builder tool to create a data package on lane configuration changes, lane occupancy, and other factors that could be transmitted to the ADS via a work zone data exchange (WZDx) feed or traveler information message (TIM).

- In response to a chat question from the City of Austin regarding the **interoperability of wearable communications**, the VTTI team noted that their smart vests broadcast using the J2735 message set. However, it is not universal that an ADS would respond to such a message even if it were able to receive them.

- Raj Rajkumar (PennDOT project team member from Carnegie Mellon University) expressed that he has seen interest among various projects in working with OEMs to standardize messages and operating procedures. Raj encouraged meeting participants to contact him if interested in such a working group.

Topic 4: State and Local Standards, Specifications, or Other General Requirements

Ashley Nylen (U.S. DOT) introduced the fourth topic of discussion, *State and local standards, specifications, or other general requirements*. She asked the group whether anyone had standards, specifications, or other

general requirements that existed in their state and local jurisdiction that they used as a starting point when building their potential requirements for ADS/AV deployers. A summary of the discussion is provided below:

- Rachel Castignoli (City of Austin's Smart Mobility Office) responded by remarking that the City of Austin has not seen a lot of ADS-work zone interactions but has dealt with issues involving ADS operations around first responders.
    - Rachel noted that the City of Austin is hearing that commercial ADS operators struggle with human traffic control: not just for work zones, but also for special events. The city has pivoted to requiring more cones and temporary signage where they previously would have employed human traffic control. Rachel noted that the technologies in development at VTTI around the smart vest and signpole sensor were intriguing. In the past year or more of deployments around the City of Austin, Rachel noted contributing factors in one collision that occurred around a work zone: while the work zone had ended, the vehicle behaved as if the work zone were present and attempted to avoid a lane that had previously been closed for the work zone but was now open. The incident was reported to the National Highway Traffic Safety Administration (NHTSA) and Rachel noted that the city may be willing to share the data with interested parties.

- The PennDOT team asked if the **Texas Department of Transportation (TxDOT) has changed their standard agreement with contractors to reflect ADS operator presence**. Tom Schwerdt (TxDOT Research Division) noted that he did not believe that construction contracts have changed in general, but Miguel Arellano (TxDOT Austin District) may be able to provide more information, particularly with respect to the "Smart Freight Corridor" project.

- The PennDOT team asked the group if anyone has used **C-V2X devices for work zone testing, and who was responsible for setting up the devices for their projects (research team or contractor)**. Tara Olds (Minnesota Department of Transportation [MnDOT]) responded that they have been approached by a contractor to test vests or pucks attached to workers that provide information to 511 or communicate lower speed limits when workers are present. She noted that a challenge of deploying these technologies is ensuring the reliability for all workers on site to be able to adequately use the technology, since many sites have hundreds of workers on a given day, ranging from a five-minute visit to full shifts. Tara noted that MnDOT is exploring testing these technologies in summer 2024.

- In response to a chat question from Jeff Loftus (FMCSA) on whether any of the call participants had conducted **work zone testing with heavy trucks**, Gunnar Rhone (PennDOT) noted that Aurora is a member of PennDOT's stakeholder group, and they plan to invite them to upcoming testing if they are interested.

Topic 5: Insurance Requirements and Safety Protocols

The PennDOT team introduced the fifth topic of discussion, *insurance requirements and safety protocols*. A

summary of the discussion is provided below:

- PennDOT posed a question about **insurance requirements**, and if any additional precautions would be necessary to ensure worker safety while ensuring the research is still valid. For example, **would using representative dummies in the work zone still lead to valid results**?

- The VTTI team noted that, because their work zone was a small-scale work zone and a staged event on a closed roadway, there were only two to three people in the work zone and they were all equipped with smart vests.

- As part of their overall safety management approach, the VTTI team required any persons potentially in the path of travel to wear a vest during the demonstration. In addition, VTTI developed an automatic emergency braking (AEB) solution to ensure that the ADS-equipped vehicle would avoid collision. VTTI was under their normal self-insured program. Austin Averkamp (from Transurban, the operator of the I-395 Express Lanes where the demonstration took place) noted that Transurban also used their general insurance coverage that applies to anyone doing work on their roadways.

- The VTTI team noted that they followed Transurban's permit application program as any other contractor would, and felt that they benefitted from having gone through that process, which included a description of the demonstration activities, personal protective equipment (PPE), potential risks, and mitigations. For example, the risk of losing communications during the demonstration was mitigated by all project members carrying push-to-talk radios, non-driver team members being on a conference call during the demo, and distribution of cellphone numbers if other communications methods failed. VTTI noted support of Virginia State Police in helping establish a presence on the roadway, and they participated in each day's safety briefing. The Virginia Department of Transportation (VDOT) and the Transurban operations center were also notified of testing days. Because the demonstration was a staged event, the research program managed work zone setup rather than a contractor.

- The VTTI team added that for their ATMA work, they worked with VDOT personnel. VTTI did not announce ATMA testing to the public ahead of time to avoid attracting potential bad actors. VTTI did, however, prepare talking points about the technology to deliver to the public if it became necessary.

Topic 6: State, Local, and Deployer Experiences with ADS Operation

Participants discussed several additional items regarding State, local and other deployer experiences. A summary of the discussion is provided below:

- Rachel Castignoli (City of Austin) stated that the City of Austin does not have regulatory authority under Texas state law, and as such, they work closely with TxDOT as a partner. Incidents that the city noted are heavily related to first responders and special events. Rachel added that, once an incident has occurred twice at the same location, the City of Austin conducts a site visit with the operator that involves a full walkaround to identify potential issues. If determined necessary, a treatment is applied

(e.g., the city installs a keep clear sign, or the operators agree to an exclusion zone). The City of Austin expects ADS operators to report incidents immediately and store incident videos for a minimum of three months. Rachel emphasized the importance of maintaining a good relationship with the operators, to be able to ask them to avoid certain areas and to share information about active work zones. She also noted that the operators work directly with the University of Texas to stay informed about large-scale construction and campus events. Rachel shared an example of why strong relationships are important: because the maximum speed of ADS operators is 35 miles per hour (mph), they are not operating on freeways or major arterials with 40 mph speed limits to avoid contributing to bottlenecks on smaller roads when incidents occur.

- Sean Brennan (PSU) asked the group if anyone has worked with **smart roadside devices**, noting that the PennDOT team is planning on deploying smart units on approximately 100 channelizers and is working on integrating the devices with WZDx messaging. He asked if anyone had any relevant development experience or lessons learned in that area.
    - Jason JonMichael (U.S. DOT) asked if Sean has connected directly with FHWA's WZDx team yet, to which Sean replied no, and that he is currently working with the manufacturer to tie in their internal communications systems and debugging capabilities. Sean noted that the connected capabilities are already present in the vendor's product but are not broadcast or packaged as C-V2X messages currently. Jason noted that he can take an action to connect the PennDOT team with FHWA's WZDx group.
- Sean also remarked that he has had conversations with VTTI about their smart vest solution; however, PSU will not permit them to do live on-road testing with a product that has not yet been commercialized. This has been a challenge, as the availability of similar commercially ready technologies is limited.
- In response to a question about **unforeseen issues with live on-road testing**, the City of Austin team described experiences with live operations, including challenges presented by police cruiser lights as well as vehicles failing to respond appropriately to human traffic control. The city has mitigated these issues by automatically alerting all ADS operators to every high-priority emergency directly from 911, and the operators enforce a 300-foot exclusion zone around the incident for an hour. The City of Austin team reiterated the importance of building relationships with operators and automating communications with them, if possible.
- In response to a question about **time-of-day and day-of-week variation on ADS testing in work zone testing**, the VTTI team shared that their project was not representative of what it would take to deploy in public traffic because the roadway was closed during their demonstration. For their ATMA deployment, VTTI focused on normal work times (between 10 a.m. and 2 p.m.), which had optimal lighting conditions and non-peak flow. The team self-limited operations to avoid testing adverse weather conditions, such as heavy rain or fog.
- The City of Austin team described a tabletop emergency response exercise that they conducted with

TxDOT, which was focused on ADS-equipped freight incidents, and recommended that others consider similar exercises. The City of Austin described the benefit of identifying potential issues with weather, type of vehicle, how to know if a vehicle is stopped, and whether the vehicle will move after emergency responders have arrived on the scene.

    - Ashley Nylen (U.S. DOT) mentioned that the Autonomous Maintenance Technology Pooled Fund Study completed a similar tabletop exercise two years ago. She noted that she would investigate whether any relevant findings from the study are available to share with the group.

- The City of Austin team shared that they are working with cities of San Francisco, Los Angeles, and Phoenix on convening a public safety meeting to discuss standardization of some of their asks to operators.

Resource Material Listing:

1. U.S. Department of Transportation, Work Zone Management for Light Vehicles Using Cooperative Driving Automation (CDA) (2023) https://highways.dot.gov/media/34676

2. U.S. Department of Transportation, Automated Vehicles and Adverse Weather Phase 3 (AVAW-3) Final Report (2021), https://ops.fhwa.dot.gov/publications/fhwahop21047/fhwahop21047.pdf

3. U.S. Department of Transportation, Collaborative Research Framework for Automated Driving System Developers and Infrastructure Owners and Operators (2021), https://ops.fhwa.dot.gov/publications/fhwahop21012/fhwahop21012.pdf

4. SAE International, Safety-Relevant Guidance for On-Road Testing of Prototype Automated Driving System (ADS)-Operated Vehicles J3018_202012 (2020), https://www.sae.org/standards/content/j3018_202012/

5. SAE International, AVSC Best Practice for In-Vehicle Fallback Test Driver Selection, Training, and Oversight Procedures for Automated Vehicles Under Test AVSC00001201911 (2019), https://avsc.sae-itc.org/#Fallback-Test-Driver-Training

6. Note to developers who are planning to use work zone data exchange or any of the tools that were developed for it: for technical support, please reach out to: CAVSupportServices@dot.gov