Automation and Adverse Weather

Workshop

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Background

Objective

This project explores how adverse weather and road weather conditions affect:

- o driver behavior
- o vehicle dynamics
- o vehicle operations
- o communications
- o sensor capabilities

…at different levels of automation

Background

- Adverse weather leads to delays and is a characteristic of 22% of crashes
- Vehicles with automated driving technology are on the market, but sensors and perception systems do not operate in all weather conditions
- Rain, wet pavement, snow, snow on pavement, fog, freezing drizzle, wind, dust, etc. affect vehicle sensors

but how?

- Inform:
  - U.S. Department of Transportation (USDOT's) research and development agenda
  - State and local operation and maintenance strategies
  - Developers and designers

Embedded in Broader USDOT Agenda

- USDOT Data for Automated Vehicle (AV) Integration
  - Facilitating and convening voluntary data exchanges to accelerate the safe integration of AVs
  - www.transportation.gov/av/data
- FHWA National Dialogue on Highway Automation
- Two upcoming opportunities
  - Road Weather Management Stakeholder Meeting
    - September 18-20, 2018, Louisville, KY
  - Automated Vehicles and Meteorology Summit
    - 23–24 October 2018 Washington, DC

Overview of the Automation and Adverse Weather Project

Project Activities

- Literature Review and Technology Scan
  - **Objectives:**
    - Research how current driving automation technologies are affected by weather
    - Identify safety and functionality gaps in existing perception and automation technology capabilities
    - Identify needs for achieving higher levels of automation, from an adverse weather conditions perspective
  - **Status:** Completed in January 2018

- Track Testing of Sensors and Sensor Systems
  - **Objective:** Test three Level 2 systems to observe performance in adverse weather conditions
  - **Status:** Conducted in March 2018

Project Activities (continued)

- Stakeholder Engagement Workshops
  - **Objectives:** Engage industry through workshops to:
    - Understand how to address the effects of adverse weather on sensory systems and human factors
    - Understand how connected automation can benefit operations in adverse weather
    - Determine what gaps exist to achieve higher levels of automation
  - **Status:**
    - Transportation Research Board (TRB) Workshop was held January 9, 2018
    - This workshop at Automated Vehicle Symposium (AVS) is the second of two

- Comprehensive Report (August 2018)

What We've Learned So Far

- The Technology Scan revealed:
  - Little is published on automation performance in adverse weather
  - Sparse authoritative detail exists about academia, industry, and government needs regarding driving automation

- Testing in adverse weather found inconsistencies in performance:
  - Between models
  - For the same models across iterations

We Need Your Help

- This is a fast-paced project and there are few opportunities for engagement
- Your input is valued and will assist in formulating the final report
- We value your perspectives on automated driving in adverse weather, including:
  - Concerns
  - Information needs
  - Research ideas

Findings from the Technology Scan

Technology Scan

- Several Level 2 systems are available, but performance under adverse weather conditions is not published
- Cameras are commonly used to sense vehicle position. Developing systems use 3D models via LiDAR. Radar and sonar are used to detect range to objects
- Owner's Manuals do qualify general adverse atmospheric and road weather conditions when sensors and automated functions should not be relied on
  - Heavy rain
  - Heavy snow on road and in atmosphere
  - Wet slush
  - Fog
  - Dust, sand, dirt
  - Wind
  - Glare, bright, shadow
  - Freezing drizzle

Challenges in Adverse Weather

- Human Factors Challenges
  - Limited research finds unfavorable outcomes when humans:
    - Over-trust in Level 2 systems
    - Under-trust in Level 4 systems
  - Adverse weather makes these problems more likely to occur and require greater attention by drivers
  - Transition of control from automation to human is difficult and is exacerbated by some conditions such as gusty winds
- Operational Challenges
  - Infrastructure for supporting adverse weather operations:
    - Short term: resilient lane markings, illumination, roadside appurtenance placement
    - Long term: outfitting and maintenance strategies evolve with technology
  - Investigation and data collection of illegal maneuvers and collisions in adverse weather

Track Testing of Driving Automation Systems in Adverse Weather Conditions

Testing Overview

- Three recent models available in North America
- Specified maneuvers
- Planned and opportune adverse weather conditions
- Data for quantitative and qualitative analyses included
  - Precise positions, heading, velocity, and time
  - High-definition videos of two front wheels, instrument cluster and forward view showing what the sensors experienced
  - Observer notes and external photos and video

Maneuvers

- Four maneuvers
  - Right and left lane departures on a straight roadway
  - Right lane departures on a curve
  - High-speed following with Adaptive Cruise Control (ACC) on a straight roadway
  - Traffic jam assist on a straight roadway
- Lane keeping performance observed informally along solid and broken lane markings under various conditions

Source: FHWA

Weather Conditions

Source: FHWA

- Planned
  - All maneuvers were conducted on dry roads in good visibility (baseline) and on wet roads and in simulated falling rain
  - Iced sensor tests were limited to traffic jam assist maneuvers
  - Low-angle sun glare tests in lane keeping
- Limited Contingency Tests Executed as Extras
  - Snow covered road tests were conducted using lane-keeping support maneuvers
  - Tests with snow showers were conducted using high-speed following maneuvers

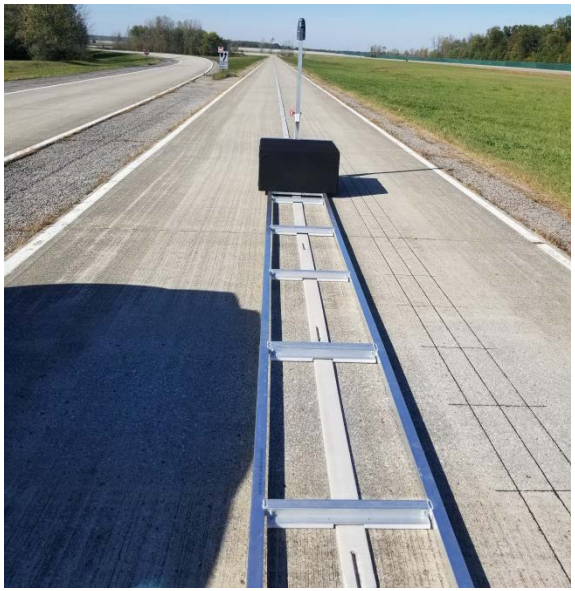
Lane Keeping Support in Rain

Source: FHWA

High Speed Following in Rain

Source: FHWA

Traffic Jam Assist (TJA) / Automatic Emergency Braking



Source: FHWA

Source: FHWA

Iced Sensors and Road Snow

Source: FHWA

Source: FHWA

Snow Covered Roads Extra

Source: FHWA

Findings from Laboratory Testing in Adverse Weather Conditions

Lane Keeping Support (LKS) Engagement and Performance

- One vehicle needed markings on both sides to engage. One could use a pavement seam and a lane marking. One needed only a single lane marking.
- Wet roadways yielded better performance, perhaps due to enhanced contrast
- Systems with lane-centering did not 'ping pong' and issued fewer Lane Departure Warnings (LDWs)
- Vehicles performed inconsistently for the same test, in dry and in rain conditions
- Performance of all three vehicles declined when rain showers were heavy and sustained

High- and Low-Speed Following

- All three performed well in dry conditions:
  - Exception: One consistently disengaged when the lead vehicle accelerated for a third time at low speed
- Heavy or sustained rainfall challenged all three at times

Iced Sensors and Limited Road Snow

- Cameras must be totally clear of ice for LKS
- One could not provide LKS after all ice was cleared and only water remained on the windshield
- Even a thin layer of ice covering the radar sensor prevents object ranging
- The heated radar sensor was good at clearing slush from most of its surface, but . . .
- One successfully performed LKS and TJA with an iced over radar sensor and cleared windshield camera

Light Snow in Air

Light snow in the air did not appear to impair vehicles' ability to detect and adjust to the speed of a slower-moving lead vehicle or perform LKS in limited informal testing.

Low Direct Sun (Glare)

- One performed well in both the straight and curve LKS tests. It did not appear to be impacted by direct sun glare
- Another was unable to maintain LKS in a curve for longer than 25 seconds, even without glare.

Human Machine Interface (HMI) Observations

- Few requirements exist for HMIs. National Highway Traffic Safety Administration (NHTSA) Vision 2.0 recommends the following driver notifications:
  - Automated driving system status (functioning, unavailable, malfunction)
  - Status of engagement in automated driving system modes (ACC, LKS, etc.)
  - Request for control transition
- A formal human factors assessment was not made as part of testing, but informal observations were documented
- Vehicle models handled the interface differently

Questions for You

Questions for Us?

Where to go for More Information

For More Information Please Contact

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Thank You!