



U.S. Department of Transportation
Federal Highway Administration

Turner-Fairbank
Highway Research Center

Impacts of Automated Vehicle (AV) on Infrastructure Research Project

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Federal Highway Administration (FHWA)
Office of Research, Development, and
Technology

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Background

- ▶ Jointly sponsored research project between FHWA Infrastructure Research and Development (R&D) (lead) with FHWA Safety R&D (support):
 - ▷ Morgan Kessler—Infrastructure R&D.
 - ▷ Abdul Zineddin and Carl Andersen—Safety R&D.
- ▶ Work performed by contractors Deepak Gopalakrishna and Paul Carlson.



Project Objectives

- ✓ Provide State departments of transportation (DOTs) information they can use today to prepare for the AV deployment-driven infrastructure changes.
- ✓ Provide DOTs with possible impacts of initial AV deployment on roadway infrastructure (over the next 10 yr).
- ✓ Illustrate areas of further research needed.
- ✗ NOT provide operational and policy recommendations.



Project Workflow



Literature Review and Coordination

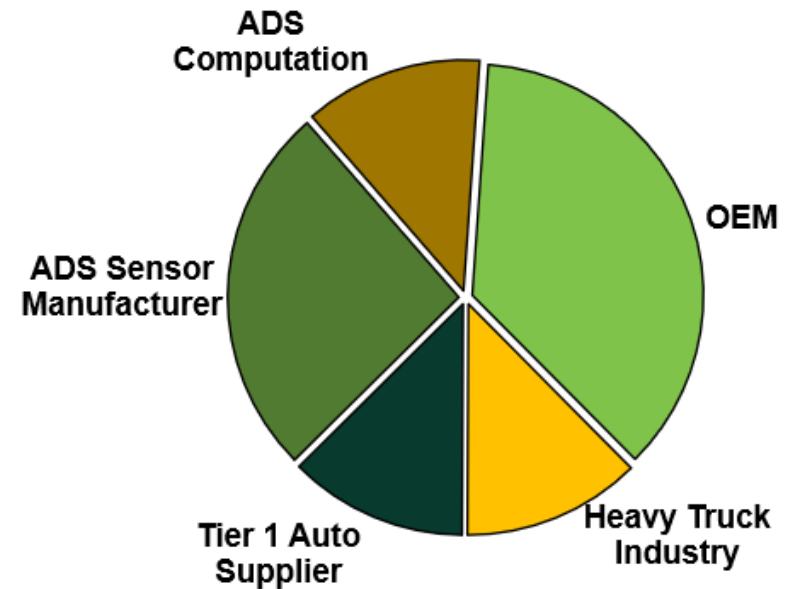
- ▶ Literature review: The impact of AV on infrastructure is an emerging area, so reports and papers available on the topic are limited.
- ▶ Project coordination efforts:
 - ▷ **Ongoing projects:** Transportation Research Board (TRB), National Cooperative Highway Research Program, FHWA, Transport Canada, and so on.
 - ▷ **Industry associations:** SAE International, American Traffic Safety Services Association, Alliance for Automotive Innovation, and so on.
 - ▷ **Professional organizations:** American Association of State Highway and Transportation Officials (AASHTO), Institute of Transportation Engineers, National Committee on Uniform Traffic Control Devices (NCUTCD), and so on.



AV Industry Interviews

Goals:

- ▶ Interactions between AVs and highway infrastructure.
- ▶ Preparedness among DOTs.
- ▶ Collaboration across stakeholder industries.



Source: FHWA.

OEM = original equipment manufacturers.



AV Industry Interviews (Cont'd)

Key findings:

- ▶ What is good for advanced driver assistance systems (ADAS) is good for automated driving systems (ADS).
- ▶ ADS sensor suite is still rapidly evolving.
- ▶ Some stakeholders believe AVs may exacerbate congestion in the near term.
- ▶ Some stakeholders believe infrastructure should be consistent and well maintained, especially regarding road markings and signage.
- ▶ Some stakeholders desire further guidance and policies at the Federal level.



DOT Stakeholder Workshops

- ▶ Workshop goal—Gather feedback from various stakeholders as presence of AV technologies increases.
- ▶ Workshop locations:
 - ▷ AASHTO, Committee on Maintenance: Grand Rapids, MI 2019.
 - ▷ TRB, AV Symposium: Orlando, FL 2019.



Source: FHWA.



Key Stakeholder Workshop Input

- ▶ Expressed interest in continued/increased collaboration between AV and highway industries.
- ▶ Desired national guidance describing how to prepare for AVs.
- ▶ Acknowledged uniform pavement markings as important in terms of supporting AV deployment.
- ▶ Expressed concerns about funding related to additional activities or maintenance beyond current DOT practices.
- ▶ Expressed concern about pavement marking maintenance/visibility in snow and ice regions.
- ▶ Reported varied infrastructure owner-operators' AV deployment readiness.



Finding Highlights for Traffic Control Devices (TCD)

Focus—Ideas for consideration related to TCDs:

- ▶ Pavement markings and their role in both ADAS and ADS deployment.
- ▶ Uniformity in application and appearance.
- ▶ Consistency in maintenance practices.
- ▶ Markings contrasted on light-colored pavements.
- ▶ NCUTCD recommendations for the next *Manual on Uniform Traffic Control Devices*.
- ▶ Additional research into more types of TCDs used by ADAS and ADS.
- ▶ Speed limit sign positioning on parallel routes (e.g., frontage roads).



Finding Highlights for Infrastructure

Focus—Physical infrastructure and operations stakeholder input:

- ▶ Heavy vehicles equipped with lane-centering technologies may accelerate pavement rutting.
- ▶ Early AV deployment may lead to increased congestion, increasing the need for and role of transportation systems management and operations.
- ▶ Digital signing can be problematic for some in-vehicle camera systems.
- ▶ Approaches and exits from toll booths can be challenging.



What “Not Ready” DOTs Reported

- ▶ “Not ready” DOTs need:
 - ▷ Maintenance plan/funding.
 - ▷ More guidance and standards.
 - ▷ Additional funding.
- ▶ These DOTs also reported that:
 - ▷ Existing road conditions are inadequate.
 - ▷ The AV industry is not fully developed (rapidly developing solutions/technology).
 - ▷ Public confidence is low.
- ▶ They are unclear about how to maximize return on investment.



What “Getting Ready” DOTs Reported

- ▶ “Getting ready” DOTs have:
 - ▷ Already started with early stages of planning.
 - ▷ An AV advocate at the executive level of their State government.
 - ▷ An existing AV-related position/office in their agency.
 - ▷ Engagements with AV developers/automotive OEMs.
- ▶ These DOTs are:
 - ▷ Beginning to train staff.
 - ▷ Updating standards and policies.
 - ▷ Conducting targeted research.



DOT Actions Reported to be Underway

- ▶ Changing pavement marking policies.
- ▶ Initiating internal task forces.
- ▶ Engaging with automotive OEMs.
- ▶ Supporting legislation.
- ▶ Updating traffic control.
- ▶ Upgrading intelligent transportation system equipment.
- ▶ Funding State-level research.
- ▶ Doing nothing (wait and see).



Suggestions for Future Research

- ▶ TCD uniformity for AVs.
- ▶ A strategic approach to updating and maintaining pavement markings.
- ▶ AV test scenarios that provide realistic expectations.
- ▶ National traffic control AV readiness assessment.



Deliverable: Three-Webinar Series

- ▶ AV Impacts Webinar 1: Traffic Control Devices (October 9, 2020).
- ▶ AV Impacts Webinar 2: Physical Infrastructure and Operations (October 16, 2020).
- ▶ AV Impacts Webinar 3: Agency Readiness (October 23, 2020).



Deliverable: TechBrief

Gopalakrishna, D., P. Carlson, D. Raghunathan.
2021. *Impacts of Automated Vehicles on Highway Infrastructure*. Report No. FHWA-HRT-21-051.
Washington, DC: Federal Highway Administration.
<https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/21051/index.cfm>.



TECHBRIEF

Impacts of Automated Vehicles on Highway Infrastructure

FHWA Publication No.: FHWA-HRT-21-051
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This document is a technical summary of the Federal Highway Administration Report *Impacts of Automated Vehicles on Highway Infrastructure* (FHWA-HRT-21-051) (Gopalakrishna et al. 2020).

BACKGROUND

Vehicles with advanced driver assistance systems (ADAS) [SAE J3016 Level 1 and Level 2] are quickly becoming common along the U.S. highway network as automated vehicle (AV) development and deployment slowly progresses toward using automated driving systems (ADS) [SAE J3016 Level 3 through Level 5] (SAE International 2018). By 2022, the transportation industry expects nearly all vehicles sold in the United States will include a forward-looking camera. This expectation is partially a result of the National Highway Traffic Safety Administration's (NHTSA's) and Insurance Institute for Highway Safety's automatic emergency braking (AEB) commitment, in which automotive manufacturers agreed to voluntarily equip all new passenger vehicles with AEB—which requires a forward-looking camera in addition to other sensors, depending on the specific manufacturer—by September 2022 (NHTSA 2019). Technologies that provide driver support features (i.e., ADAS) are the building blocks for ADS. Understanding today's technology needs and future technology timelines can help infrastructure owners and operators (IOOs) plan and design their networks to maximize AV safety potential.

This document provides an overview of a multiphase research effort that involved a comprehensive literature review, engagement with highway IOOs, and interviews with industry experts and key stakeholders to document the potential impact of AVs on highway infrastructure. The research team identified the state of the practice among IOOs, knowledge gaps, and agency preparedness levels for the impact of AV use on highway infrastructure. This document does not cover the operations or policy aspects of AV infrastructure impacts because its goal is to provide information to IOOs as they prepare for the eventual infrastructure evolution driven by AV deployment.

OBJECTIVE

The primary objectives of this research project were to assess and understand the demands and potential impacts of AVs on current infrastructure assets as well as future infrastructure. Some of the important research questions considered for the project included the following:

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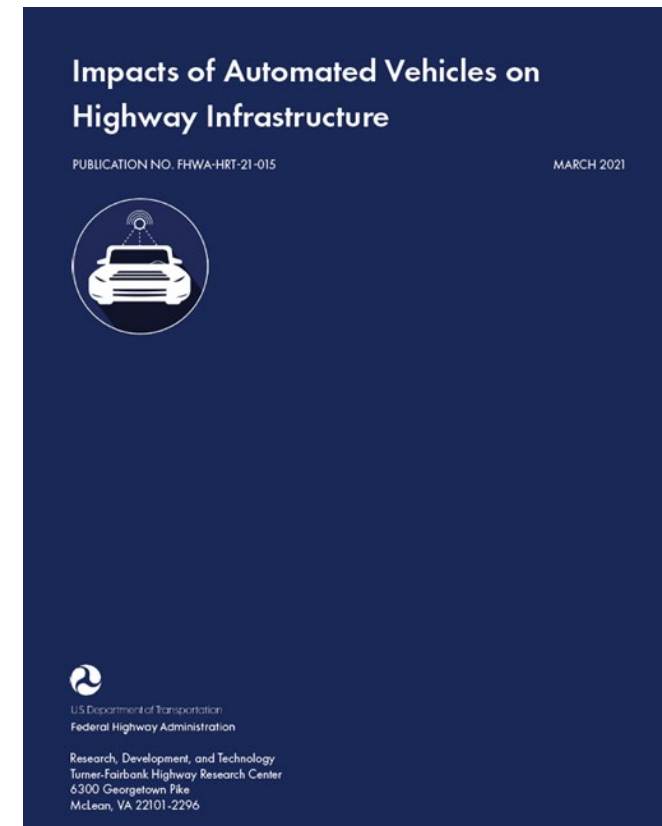
Source: FHWA.

Deliverable: Final Report

Gopalakrishna, D., P. Carlson, P. Sweatman, D. Raghunathan, L. Brown, and N. U. Serulle.

2021. *Impacts of Automated Vehicles on Highway Infrastructure*. Report No. FHWA-HRT-21-015. Washington, DC: Federal Highway Administration.

<https://www.fhwa.dot.gov/publications/research/operations/21015/index.cfm>



Source: FHWA.

Questions?



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