# INTERNATIONAL SCAN OF CONNECTED AND AUTOMATED VEHICLE TECHNOLOGY DEPLOYMENT EFFORTS

December 2016

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**International Scan of Connected and Automated Vehicle Technology Deployment Efforts**
February 3, 2017

MDOT REQ. NO. 1259, Connected and Automated Vehicle Industry Coordination
Task A.10. Update International Survey of Best Practices in ITS/CAV

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# ACKNOWLEDGMENTS

This document is a product of the Center for Automotive Research under a *State Planning and Research Grant* administered by the Michigan Department of Transportation.

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# 1 INTRODUCTION

This report is the result of a continuous effort of the Michigan Department of Transportation (MDOT) and Center for Automotive Research (CAR) to document global development and deployment of connected and automated vehicle technologies. In just the last few years, research and pilot projects have proliferated rapidly. Connected and automated vehicle technology development is now a global phenomenon.

While research and development projects have become practically countless, deployment remains rare. Only a fraction of recently developed technology is available to real-world drivers. *Automated driving systems* (defined as SAE levels 3-5)[1] have thus far been publically deployed only in strictly-controlled environments and experimental test pilots. Connected vehicle systems are increasingly used for fleet management and infotainment, but the life-saving potential of connected vehicles through cooperative intelligent transportation systems (C-ITS) has scarcely been tapped.

Considering the complexity of transportation systems, vehicle manufacturers cannot deploy many transformational technologies on their own. Bringing advanced connected and automated vehicle technology to our public roads requires coordination with public agencies at various levels of government.

This report documents the most significant projects of 2016 where public-private partnerships worked together to advance the state of connected and automated vehicle technologies through real-world testing and deployment. Through this process, MDOT will maintain current knowledge of the most successful projects and global best practices. This information will help ensure that MDOT and the state of Michigan remain among the leaders in development and deployment of the world's most beneficial transportation technologies.

[1] This report generally adopts the terms and taxonomy as described in SAE J3016 (2016), "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles." However, to the extent that this report describes and summarizes global projects and efforts, the terms used in those projects are adopted as appropriate. For example, vehicles equipped with automated driving systems are often called "autonomous vehicles," an imprecise term that is nonetheless widely used.

# 2 UNITED STATES FEDERAL EFFORTS

There is extensive public-private collaboration to deploy connected and automated vehicle technology in the United States. The U.S. DOT is leading a nationwide public-sector effort through the ITS Strategic Plan.[2] Additionally, several states have initiated state-level efforts to encourage the development and deployment of connected and automated vehicles. This chapter introduces major public sector and public-private cooperative efforts to develop and deploy connected and automated vehicle technology.

## 2.1 U.S. DOT CONNECTED VEHICLE PROGRAM

The U.S. DOT Connected Vehicle Program focuses on a specific set of connected vehicle standards and technologies centered around dedicated short-range communication (DSRC) wireless access in a vehicular environment (WAVE).[3] This technology is similar to Wi-Fi, but has been designed specifically to enable connected vehicle applications. The current suite of technologies and standards are the result of decades of refinement through pilot projects and technology breakthroughs. The most major ongoing efforts are described below.

FIGURE 1: U.S. DOT CONNECTED VEHICLES VISION[4]

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[2] Barbaresso et al. "U.S. DOT's Intelligent Transportation Systems (ITS) ITS Strategic Plan 2015-2019." U.S. DOT. Booz Allen Hamilton. 2014.

[3] The U.S. DOT has adopted several industry standards to facilitate interoperability between devices. A description of connected vehicle standards is available at: https://www.standards.its.dot.gov/LearnAboutStandards/ResearchInitiatives

[4] Image: https://www.transportation.gov/fastlane/connected-vehicle-pilots-coming-region-near-you.

## CONNECTED VEHICLE TESTBEDS

U.S. DOT has a long-established connected vehicle testbed in Southeast Michigan available to DSRC technology and application developers. U.S. DOT is expanding support to affiliated partner testbeds in California, New York, and elsewhere.[5]

The goal of this affiliated structure is to allow pre-competitive information-sharing and cooperative development of a common technical platform.[6] As of November 2016, the U.S. DOT reports agreements with 87 public, private, and academic organizations.[7] Collaborating in these testbed sites provides access to U.S. DOT support staff and resources. Testbeds offer a variety of technologies for users utilize, including:

- Signal Phase and Timing (SPaT)
- Geometric Intersection Description (GID) data broadcast
- Available vehicle awareness devices (VADs), aftermarket safety devices (ASDs), and roadside units (RSUs).
- U.S. DOT preliminary Security Credentials Management System (SCMS).

## TESTBED RESEARCH PROJECTS

These testbeds have been funded through the U.S. DOT Pooled Funds Study which began in 2009 and is currently scheduled to conclude in August 2017. There are two ongoing projects (as of November 2016) being run through the Connected Vehicle Pooled Fund Study.[8]

One project is “5.9 GHz Dedicated Short-Range Communication Vehicle-based Road and Weather Condition Application: Phase 2.” This effort will develop and test the acquisition of road and weather condition information from 5.9 GHz DSRC-equipped public agency vehicles, transmit this data via RSE to a central server, and ultimately to store it for use by agency maintenance personnel.

[5] U.S. Government Accountability Office (GAO). “Intelligent Transportation Systems: Vehicle-to-Infrastructure Technologies Expected to Offer Benefits but Deployment Challenges Exist.” GAO-15-775. September 2015.
[6] Affiliated Test Bed Memorandum of Agreement, version 20140130.
[7] http://www.its.dot.gov/research_archives/testbed/testbed_affiliated.htm accessed Nov 2016.
[8] University of Virginia Center for Transportation Studies, http://www.cts.virginia.edu/cvpfs_research/ accessed November 2016.

Phase 1 of this project, now completed, developed a suite of onboard and roadside equipment and software to enable data gathering from vehicles to roadside collectors. Phase 2 will build off of Phase 1 and provide data aggregation from RSUs to back-office servers with end-to-end system evaluation. In addition, the system is planned to expand from Virginia to Michigan and New York State.[9]

The other current project is "Basic Infrastructure Message Development and Standards Support." The goals of this project are to develop a Basic Infrastructure Message (BIM) and collaborate with the relevant standards-development organizations. Having a standard BIM would help the OEMs and third-party application providers develop technology based on specific and reliable communication from infrastructure components. In addition, this will also help the public transportation agencies to know what kind of information to broadcast from their Road Side Equipment (RSE).[10]

Recently-completed testbed research projects include, "Best Practices for Surveying and Mapping Roadways and Intersections for Connected Vehicle Applications,"[11] and "Multi-Modal Intelligent Traffic Signal System – Phase II: System Development, Deployment and Field Test."[12]

## CONNECTED VEHICLE PILOT DEPLOYMENT PROGRAM

The U.S. DOT has funded a first wave of pilot deployment sites. The initial (concept development) phase of the pilots concluded in late 2016. Phase two, now underway, will design, deploy, and conduct preliminary tests, leading to an 18-month period of routinized operation and maintenance in Phase three. It is anticipated that the sites will then transition to permanent operational elements in an expanding national connected vehicle environment. The U.S. DOT has selected three pilot sites, where teams are moving towards deployment of a variety of V2V and V2I applications, as described below.

### NEW YORK CITY

The primary goal of the New York City pilot deployment is to improve safety through the reduction of vehicle and pedestrian crashes. The New York Pilot

[9] Ibid.
[10] Ibid.
[11] Farrel, Todd, and Barth. "Best Practices for Surveying and Mapping Roadways and Intersections for Connected Vehicle Applications," May 15, 2016.
[12] University of Arizona. "Multi-Modal Intelligent Traffic Signal System – Phase II: System Development, Deployment and Field Test." September 2016.

is uniquely designed to evaluate the benefits and challenges of implementing connected vehicle technology in a dense urban environment. The deployment team is planning to install around 280 RSEs around the city. They anticipate installing DSRC units in up to 10,000 fleet vehicles including cabs and buses. Additionally, they plan to test pedestrian safety applications with up to 100 pedestrian-based DSRC units. The New York team has proposed an extensive series of performance measure metrics in order to statistically determine the benefits to safety and mobility.[13, 14]

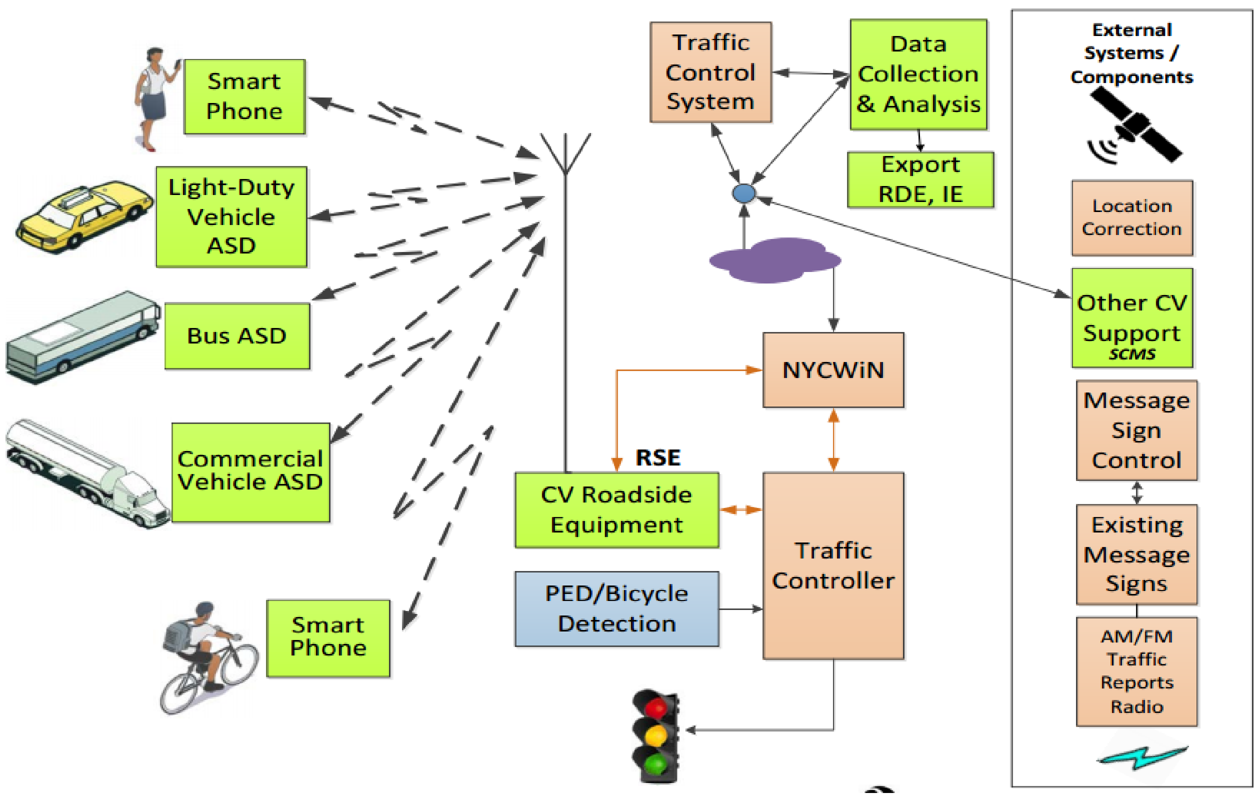


FIGURE 2: NEW YORK CITY CONNECTED VEHICLE PILOT DEPLOYMENT PROJECT CONCEPT[15]

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[13] Connected Vehicle Pilot Deployment Program, "Performance Measurement and Evaluation Support Plan, New York City." June 6, 2016.

[14] Additional information regarding New York City deployment initial Concept of Operation is available at: http://www.its.dot.gov/pilots/pdf/NYC_ConOpsWebinar.pdf

[15] Source: Ibid note 13.

### TAMPA, FLORIDA

The Tampa, FL pilot deployment team anticipates deploying multiple applications of DSRC V2X technology that address mobility, environment, safety, and agency efficiency. Combinations of applications are grouped together into six use cases, as follows:

TABLE 1: TAMP, FL PILOT DEPLOYMENT USE CASES AND APPLICATIONS[16]

| Use Case | Applications |
|---|---|
| **Morning Backups and Congestion** | V2V Safety (Forward Collision Warning and Electronic Emergency Brake Light)<br>Curve Speed Warning<br>Intelligent Traffic Signal System (I-SIG) |
| **Wrong Way Incidents[17]** | Intersection Movement Assist (IMA)<br>Red Light Violation Warning<br>Probe-enabled Traffic Monitoring<br>Intelligent Traffic Signal System (I-SIG) |
| **Pedestrian Safety** | Pedestrian in Signalized Crosswalk Warning<br>Mobile Accessible Pedestrian Signal (PED I-SIG) |
| **Transit Signal Priority, Optimization, and Safety** | Intelligent Traffic Signal System (I-SIG)<br>Transit Signal Priority (TSP) |
| **TECO Line Streetcar Conflicts** | Vehicle Turning Right in Front of Bus Warning<br>Intelligent Traffic Signal System (I-SIG) |
| **Enhanced Signal Coordination and Traffic Progression** | Probe-enabled Traffic Monitoring<br>Intelligent Traffic Signal System (I-SIG) |

### WYOMING

The Wyoming connected vehicle pilot will be deployed along Interstate 80 at multiple points across the state. The Wyoming team plans on installing DSRC equipment in 400 vehicles including WYDOT snowplows and heavy commercial vehicles. I-80 is a heavily-trafficked freight corridor subject to extreme weather events, often leading to severe crashes and excessive emergency response time. The Wyoming deployment will emphasize DSRC for advisories, roadside alerts, parking notifications, and dynamic travel guidance to commercial and fleet vehicles.[18]

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[16] Connected Vehicle Pilot Deployment Program, "Performance Measurement and Evaluation Support Plan, Tampa." June 6, 2016.
[17] Wrong-way incidents are a relatively frequent occurrence on the reversible express lanes to the Selmon Expressway.
[18] http://www.its.dot.gov/pilots/pilots_wydot.htm.

### SMART CITY CHALLENGE

The U.S. DOT introduced a $40 million Smart City grant competition to "mid-sized" American cities. Seventy-eight applications were received. Of these, six were awarded a $100,00 planning grant to develop a final proposal. The winner of the $40 million grant is Columbus, Ohio.

Among the several investment options included in the Columbus Smart City proposal, the team proposes to add DSRC technology to busses and public-safety vehicles for signal priority. Additional plans call for a fleet of "last-mile" automated public transit vehicles that will include DSRC connectivity.[19]

## 2.2 U.S. DOT AUTOMATED VEHICLE PROGRAM

The U.S. DOT ITS Strategic Plan emphasized automated vehicle technology in addition to connected vehicles. The U.S. DOT pledges to focus on the "advancement of technologies and systems to enable the smooth and safe introduction of automated features into the nation's vehicles and transportation systems."[20] The U.S. DOT conceptualizes automated vehicle development as integrated with the Connected Vehicle Program—combining both connectivity and automation to address ITS Program goals (Figure 3).

U.S. DOT NHTSA has been working with industry developers to create a national regulatory framework that will facilitate the introduction of vehicle automation features—including fully self-driving vehicles. For example, NHTSA has stated that any automated vehicle features not specifically subject to Federal Motor Vehicle Safety Standards (FMVSS) are de-facto compliant with federal safety regulations.[21, 22] NHTSA also commissioned a complete review of FMVSS rules to highlight areas that may need to be addressed to allow for specific features of automated vehicles.[23] Acknowledging that FMVSS standards will be difficult to amend, NHTSA has highlighted a

[19] City of Columbus Smart City Grant Proposal. 2016.
[20] Barbaresso, et al. "U.S. DOT's Intelligent Transportation Systems (ITS) Strategic Plan 2015-2019. Booz Allen Hamilton, U.S. DOT. December 2014.
[21] Paul A. Hemmersbaugh, NHTSA Chief Counsel. Response to Request for Interpretation of FMVSS by Chris Urmson, Director of the Google Self Driving Car Project.
[22] Paul A. Hemmersbaugh, NHTSA Chief Counsel. Response to Request for Interpretation of FMVSS by Samuel Campbell of BMW of North America, LLC, January 4 2016.
[23] Kim et al. "Review of Federal Motor Vehicle Safety Standards (FMVSS) for Automated Vehicles: Identifying potential barriers and challenges for the certification of automated vehicles using existing FMVSS." U.S. DOT Volpe. March 2016.

method that manufacturers may use to request temporary exemptions for non-FMVSS-compliant vehicles.[24]

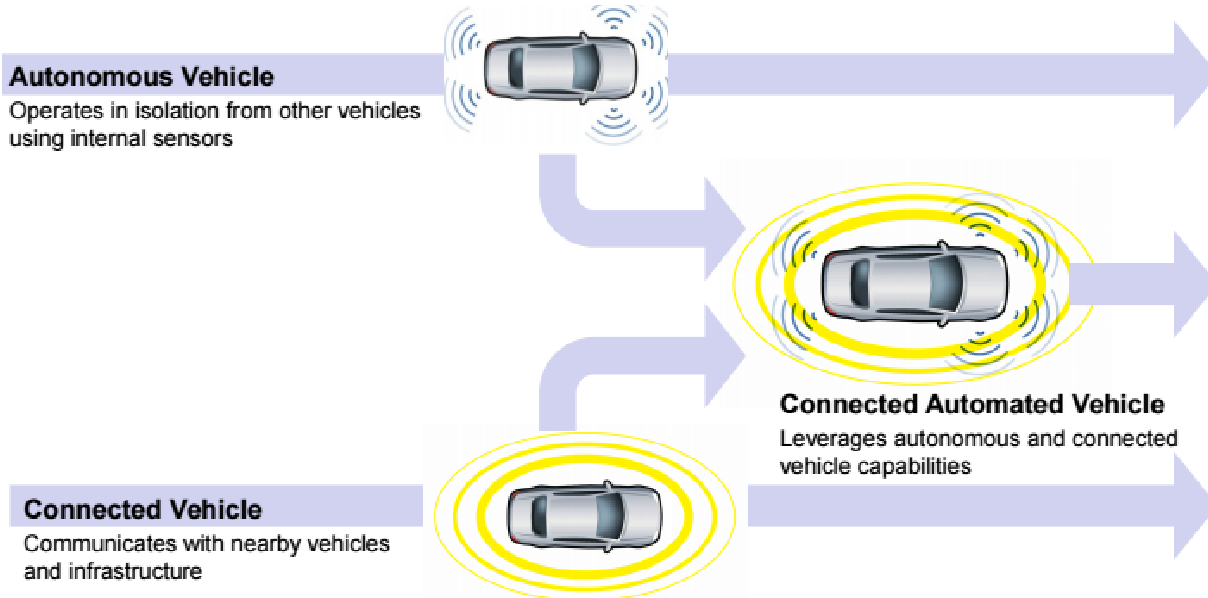


FIGURE 3: U.S. DOT VISION OF CONNECTED/AUTOMATED VEHICLE[25]

NHTSA provided an extensive *Federal Automated Vehicles Policy* document in September 2016.[26] The NHTSA policy document has no force of law in itself; it does not impact existing statutory or regulatory requirements. However, the document *does* imply that NHTSA is seriously considering initiating future rulemakings. One potential mandate would require manufacturers of automated vehicles to submit a 15-point safety assessment to obtain approval to introduce an automated vehicle to consumers. In the meantime, NHTSA will request manufacturers voluntarily provide the 15-point safety assessment.[27, 28]

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[24] Ibid Note 21.
[25] Source: Kevin Dopart. Presentation: "U.S. DOT Automated Research Program." U.S. DOT ITS JPO. Shown at: Automated Vehicle Symposium, 2014. Burlingame, CA. July 17, 2014.
[26] U.S. DOT NHTSA. *Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety.* September 2016.
[27] Dennis and Wallace. "Federal Automated Vehicles Policy: Overview and Comments." Center for Automotive Research. September 22, 2016.
[28] Considering the anti-regulatory bend of the current Trump Administration, NHTSA is unlikely to initiate any rulemakings on this subject in the near term. Even the future of the effort to request voluntary data is uncertain.

## AUTOMATED VEHICLE PROVING GROUNDS

In January 2017, the U.S. DOT selected ten sites as automated vehicle proving ground pilot sites to "encourage testing and information sharing around automated vehicle technologies."[29] The ten designees are:[30]

- City of Pittsburgh and the Thomas D. Larson Pennsylvania Transportation Institute
- Texas AV Proving Grounds Partnership
- U.S. Army Aberdeen Test Center
- American Center for Mobility (ACM) at Willow Run
- Contra Costa Transportation Authority (CCTA) and GoMentum Station
- San Diego Association of Governments
- Iowa City Area Development Group
- University of Wisconsin-Madison
- Central Florida Automated Vehicle Partners
- North Carolina Turnpike Authority

## FHWA TRUCK PLATOONING PROJECT

Under the FHWA Exploratory Advanced Research project, "Heavy Truck Cooperative Adaptive Cruise Control Evaluation, Testing, and Stakeholder Engagement for Near Term Deployment," the FHWA and Auburn University are evaluating the commercial feasibility of Driver Assistive Truck Platooning (DATP). DATP is a form of Cooperative Adaptive Cruise Control for heavy trucks (two truck platoons). DATP combines DSRC V2V connectivity and vehicle automation to facilitate Cooperative Adaptive Cruise Control (CACC) between two or more heavy trucks. Preliminary results have suggested that DATP can significantly reduce fuel consumption.[31, 32]

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[29] U.S. DOT. "U.S. Department of Transportation Designates 10 Automated Vehicle Proving Grounds to Encourage Testing of New Technologies." Press Release. Jan 19, 2017.
[30] Ibid.
[31] Bevly et al. "Heavy Truck Cooperative Adaptive Cruise Control: Evaluation, Testing, and Stakeholder Engagement for Near Term Deployment: Phase One Final Report." Auburn University. U.S. DOT FHWA. April 2015.
[32] American Trucking Association (ATA). White Paper: "Automated Driving and Platooning Issues and Opportunities." ATA Automated Driving and Platooning Task Force. September 2015.

## 2.3 U.S. ARMY TARDEC TRUCK PLATOON TESTING

The U.S. Department of Defense (DOD) is leveraging DSRC technologies developed in the commercial sector to explore platooning of military vehicles. The U.S. Army Tank Automotive Development Center (TARDEC) is testing communications capabilities necessary for automated platooning on public roads in partnership with Michigan Department of Transportation. The project is evaluation DSRC for both V2V and V2I communications.[33]

## 2.4 DOE SYSTEMS AND MODELLING FOR ACCELERATED RESEARCH IN TRANSPORTATION (SMART)

In 2016, the National Renewable Energy Laboratory (NREL)[34] launched the Sustainable Mobility Initiative. This program promises to be an additional source of US government research efforts to develop and deploy advanced vehicle and transportation technologies.[35] An initial effort, NREL has partnered with the Colorado Department of Transportation on exploratory research, and anticipates future partnerships.[36]

[33] David C. Smith. “Army Trucks and Michigan DOT Talk to Each Other on I-69.” *WardsAuto*. June 29, 2016.
[34] NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.
[35] http://www.nrel.gov/transportation/sustainable-mobility-initiative.html accessed June 2016.
[36] http://www.nrel.gov/news/features/2016/21622 accessed June 2016.

# 3 U.S. STATE-LEVEL LEGISLATION AND REGULATION

In 2011, Nevada surprised many by becoming the first state to adopt legislation addressing automated vehicles.[37] As of November 2016, eight U.S. States have passed relevant laws.[38] The most common purposes of state legislative efforts have been to:

- Introduce Definitions
- Regulate On-road Testing
- Regulate Deployment
- Address Liability

Table 2 shows the eight states that have enacted legislation with reference to the topics covered.

TABLE 2: ITEMS ADDRESSED IN STATE AUTOMATED VEHICLE LEGISLATION

| | Introduce Definitions | Regulate Testing | Regulate Deployment | Address Liability |
|---|---|---|---|---|
| **California** | X | X | X | X |
| **Florida** | X | X | | X |
| **Louisiana** | X | | | |
| **Michigan** | X | X | X | X |
| **Nevada** | X | X | X | X |
| **North Dakota** | X | | | |
| **Tennessee** | X | | | |
| **Utah** | X | | | |

Additional uses of legislation have served, for example, to direct state-government research agencies to report on the issue, and to exempt automated vehicle technologies from certain legal provisions. Even states that have covered the same topics have often done so in different and conflicting ways. Details of state efforts are provided below.

[37] LegiScan. Nevada AB 511. Accessed February 2015 at: https://legiscan.com/NV/bill/AB511/2011

[38] Stanford CIS Automated Driving Legislative and Regulatory Action wiki. Accessed November 2016.

## 3.1 CALIFORNIA

California enacted a law in 2012 directing the California DMV to enact regulations for both the public testing and consumer use of automated vehicles. The DMV adopted regulations for public testing in January 2014, but has yet to adopt regulations for consumer use. California's regulatory framework for testing is generally seen as effective. Though, there has been occasional confusion as to what activities the regulations apply. For example, Uber recently ceased testing in San Francisco following a dispute with the DMV over testing regulations.[39] Nevertheless, 21 developers have received, autonomous vehicle testing permits in California.[40]

- Volkswagen Group of America
- Mercedes Benz
- Google (Figure 4)
- Delphi Automotive
- Tesla Motors
- Bosch
- Nissan
- GM Cruise LLC
- BMW
- Honda
- Ford
- Zoox, Inc.
- Drive.ai, Inc.
- Faraday & Future Inc.
- Baidu USA LLC
- Wheego Electric Cars, Inc.
- Valeo North America, Inc.
- Telenav, Inc.
- NVIDIA Corporation
- AutoX Technologies Inc.

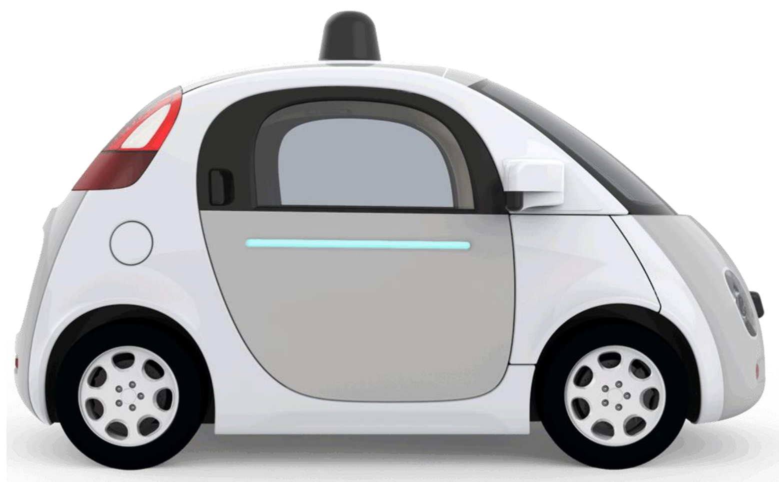

FIGURE 4: GOOGLE SELF-DRIVING CAR

[39] Darrell Etherington. "Uber stops San Francisco self-driving pilot as DMV revokes registrations." *TechCrunch*. Dec 21, 2016.

[40] https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/testing accessed February 2017. List is provided in chronological order of approval.

Per California's testing regulations, companies testing automated vehicles on public roads must report all accidents (regardless of if police were involved) and disengagements.[41] Accidents are reported monthly. Disengagement reports are submitted annually.

California's 2012 legislation directs the DMV to adopt a complete regulatory framework for the *commercial* deployment of autonomous vehicles (non-test vehicles available to consumers). An initial draft of proposed regulations was offered December 2015. After a rigorous public input process, the draft regulations were revised, and a new draft published Sept 30, 2016.[42]

As of February 2017, the California DMV has not yet adopted a final set of regulations for consumer use of automated vehicles, and a timeline to adoption is unclear. The latest draft was widely criticized by both the traditional auto industry and technology developers as being far too restrictive.[43, 44] Even [former] NHTSA Administrator Mark Rosekind suggested in a U.S. Congressional committee hearing that California's proposed regulations might be overly restrictive.[45] Furthermore, some policy analysts perceive many points of incoherence in California's approach stemming from flaws in the original legislation.[46]

### GOMENTUM STATION

California enacted an additional law in 2016 that allowed the Contra Costa Transportation Authority to conduct pilot testing of vehicles without manual controls on public roads within the footprint of the *GoMentum Station* vehicle test facility in Contra Costa County.[47] The GoMentum Station has been named as one of ten federal automated vehicle proving grounds.[48]

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[41] https://www.dmv.ca.gov/portal/wcm/connect/d48f347b-8815-458e-9df2-5ded9f208e9e/adopted_txt.pdf?MOD=AJPERES&CONVERT_TO=url&CACHEID=d48f347b-8815-458e-9df2-5ded9f208e9e accessed June 2016.

[42] https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/auto accessed February 2017.

[43] David Shepardson. "Google, automakers object to California rules for self-driving cars." *Reuters.* Oct 20, 2016.

[44] Ryan McCauley. "3 Concerns Automakers Have with California's Autonomous Vehicle Regulations." *GovTech.com, FutureStructure.* October 20, 2016.

[45] Brian Fung. "Federal officials take aim at California's plan for self-driving cars." *The Washington Post.* Nov 15, 2016.

[46] E.g., Prof. Robert Peterson. Correspondence to Ca DMV, Re: Proposed Autonomous Vehicle Regulations. February 23, 2016.

[47] CA AB 1592, Bonilla. Autonomous vehicles: pilot project.

[48] Supra section 2.2.

## 3.2 FLORIDA

Florida was the second state (after Nevada) to enact legislation related to automated vehicles. Unlike Nevada, Florida's 2012 law did not require follow-up regulation from any state agency (except submission of a research report). The law applies only to *testing* of "autonomous" vehicles (not consumer use), and mandates some general requirements on the driver and $5 million proof of insurance coverage.

Florida amended automated vehicle law in 2016 to loosen restrictions on testing and specifically allow truck platooning. As of early 2014, Florida had received no applications to test autonomous vehicles[49] and this appears to remain the case as of November 2016. Florida and FDOT continue to focus on automated vehicle technology, for example through the FDOT Florida Automated Vehicles (FAV) Program.[50] Additionally, a partnership between the city of Orlando and local academic, public, and industry interests was named as a federal automated vehicle proving ground.[51]

## 3.3 LOUISIANA

Louisiana enacted a law in 2016 that introduced definitions related to automated vehicles into the state highway code. Definitions included "autonomous technology," "driving mode," "dynamic driving task," "operational," "strategic," and "tactical." The law included no further provisions for regulation.[52]

## 3.4 MICHIGAN

In 2013, Michigan became the fourth state to specifically regulate the testing of automated vehicles. Public Acts 231 and 251 of 2013 updated Michigan's legal code to allow manufacturers, suppliers, and upfitters of automated vehicle technology to test prototype automated driving systems on public roads when registered with a special license plate (an 'M-plate') provided by the Michigan Secretary of State.

[49] Florida Dept. of Highway Safety and Motor Vehicles. "Autonomous Vehicle Report." February 10, 2014.
[50] Florida DOT Florida Automated Vehicles (FAV), http://www.automatedfl.com/ , accessed November 2016.
[51] Supra section 2.2
[52] LA HB No. 1143, 2016. Enrolled as Act No. 318.

In 2016, Michigan updated the legislation to refine key definitions, remove a prohibition on deployment of automated vehicles, introduce a regulatory framework for an "on-demand motor vehicle network," and add other various automated vehicle-related language to the legal code. One provision of Michigan's law limits local authority to impose restrictions and fees on automated vehicles.

Between March 2012 and March 2015, the following companies have been issues M-plates with the explicit purpose of testing automated vehicle technology.[53]

- Autoliv Electronics America
- Continental Automotive Systems
- Dura Automotive Systems
- Magna Electronics
- Quantum Signal
- The University of Michigan
- Robert Bosch LLC
- Roush Industries
- Valeo

The details of testing activities in Michigan are not well known. Michigan's M-plate program does not require a detailed description of the technology being developed. Beyond the listed companies, some manufacturers and suppliers are likely testing automated vehicle technology under the M-plate program without having explicitly stated the nature of the technology being developed. Additionally, there may be testing of automated vehicle systems on Michigan's roads (and elsewhere) with normally-registered vehicles. A production vehicle could be upfitted with an automated driving system and registered, licensed, and operated under standard vehicle codes, and this would not likely violate any law so long as federal safety standards are not compromised.[54]

[53] List was compiled by review of M-plate applications provided to CAR by the Michigan Secretary of State in 2015.

[54] Additionally, established manufacturers may test non-FMVSS-certified prototype vehicles on public roads through a provision in the recent federal transportation funding law, the FAST Act.

## 3.5 NEVADA

FIGURE 5: NEVADA AUTONOMOUS TEST VEHICLE LICENSE PLATE

Nevada was the first state to adopt automated vehicle legislation in 2011. Nevada's 2011 bill did not provide much detail regarding how automated vehicles would be regulated, but authorized and instructed the state DMV to adopt regulatory language. The Nevada DMV adopted regulations in March 2012. Nevada's statutory language was amended in 2013 to incorporate previously adopted regulatory language regarding definitions, testing, deployment, and liability.[55]

Though both testing and consumer deployment regulations have been adopted, Nevada is currently accepting applications only for testing, stating that "autonomous vehicles are not yet available to the general public."[56] At least six companies have been licensed to test automated vehicles in Nevada: Google, Audi, Continental, Delphi, Hyundai-Kia, and Daimler.[57] Upon approval, the Nevada DMV provides testers with a special distinct license plate (Figure 5).

There are recent indications that Nevada's regulation is not working as intended. A California-based company called Otto that is developing driving automation systems for commercial vehicles conducted a demonstration on I-80 in Nevada without applying for, or receiving a license.[58] The DMV knew of the demonstration before-hand and explicitly warned Otto that they would be in violation.[59] Otto went ahead with testing, including a publisized video.[60] Nevada's DMV did not impose any penalties on Otto.[61]

Otto's testing in Nevada continued for several weeks without seeking official approval, and now appears to have moved on-road testing elsewhere. Rather

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[55] NV SB313, 2013, enrolled as Chapter 377.
[56] http://www.dmvnv.com/autonomous.htm accessed June 2016.
[57] It could not be confirmed if additional companies have been licensed but not publicized, or if the companies listed remain currently licensed to conduct testing.
[58] Mark Harris. "How Otto Defied Nevada and Scored a $680 Million Payout from Uber." Backchannel. November 28, 2016.
[59] Ibid.
[60] Otto – Self-driving Trucks. YouTube. May 16, 2016. https://www.youtube.com/watch?v=bK76W1kH4jA&feature=youtu.be&t=28.
[61] Ibid note 58.

than apply to test automated trucks in the state, Otto applied, and was approved, to establish Nevada's first Autonomous Vehicle Certification Facility (AVCF). Nevada's regulations established the AVCF concept with the intent of having a formal third-party testing facility validate that automated vehicles are safe for consumer use. Otto's AVCF will only be used to certify vehicles developed by Otto and Otto's parent company, Uber.[62]

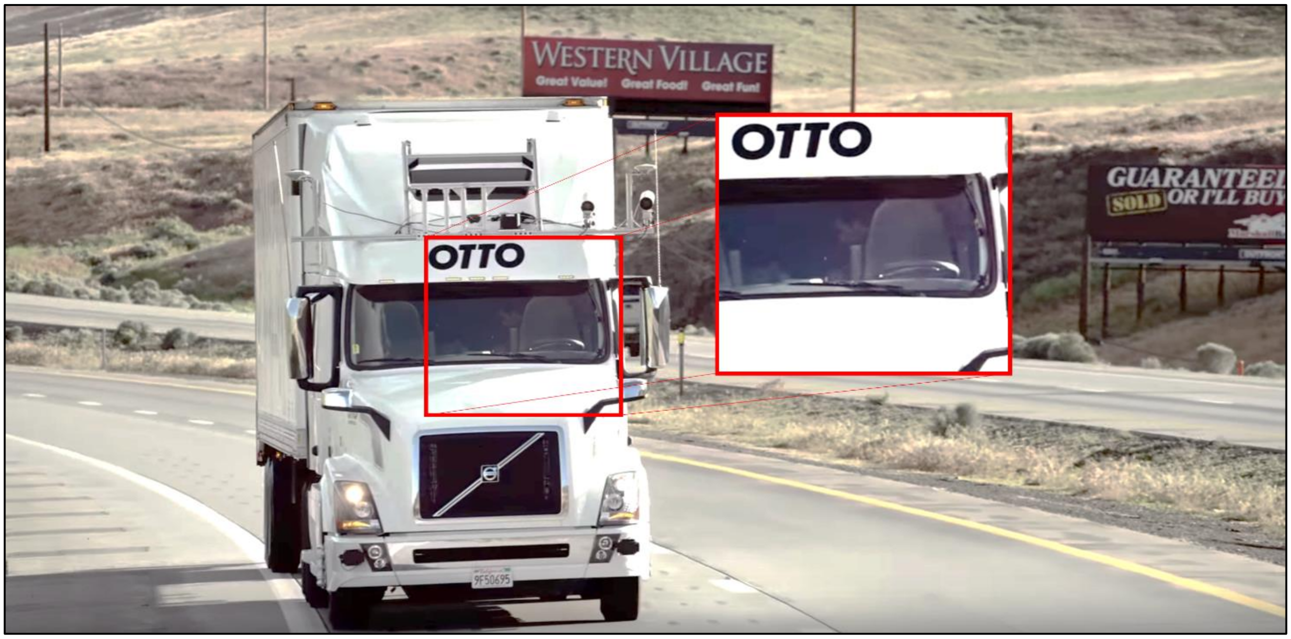


FIGURE 6: OTTO PUBLIC TEST DRIVE IN NEVADA MAY 2016—ENGINEER IS NOT IN DRIVER'S SEAT OR ACTIVELY MONITORING SYSTEM PERFORMANCE.[63]

[62] Ibid.
[63] Image: Ibid note 60.

## 3.6 NORTH DAKOTA

In 2015, North Dakota passed a law defining "automated motor vehicle" and directing the legislative management (a research division of North Dakota's state government) to consider studying the issue. The legislation defined "automated motor vehicle" as equivalent to SAE level 5.[64] Level 5, "full driving automation" describes extremely advanced autonomous driving technology that may not be introduced to the public for decades, if ever. The legislative management did not prioritize this request and did not author a report.

## 3.7 TENNESSEE

Tennessee enacted a law in 2015 precluding the possibilities of local jurisdictions from prohibiting automated vehicles.[65] An additional 2016 law introduced key terms into the state legal code, including "autonomous technology," "driving mode," "dynamic driving task," "operational," "strategic," and "tactical."[66] Automated vehicles are not further regulated in Tennessee.

## 3.8 UTAH

Utah has enacted two laws pertinent to automated and connected vehicles. One law defines "autonomous vehicle" and directs the Utah Department of Public Safety to prepare a report on autonomous vehicles, including recommendations for further legislative and regulatory action. The resulting report concluded that "it may be premature to implement new policies or adopt new legislation at this time."[67]

The law also permitted state agencies to contract private parties to test automated vehicles within the state.[68] The other law exempts platooning vehicles from a requirement to maintain a two-second following distance,

[64] ND HB No 1065 of 2015.
[65] TN SB No. 598, enrolled as Tennessee Public Chapter No. 307.
[66] TN SB No. 1561, enrolled as TN Public Chapter No. 1561.
[67] Utah Department of Transportation (UDOT). *Best Practices for Regulation of Autonomous Vehicles on Utah Highways.* October 2016.
[68] UT HB 280 of 2016.

assuming the platooning is conducted as part of a test approved by the state Departments of Transportation and Public Safety.[69]

## 3.9 MASSACHUSETTS

Massachusetts has not passed any law specific to automated vehicles or adopted formal regulations. However, Governor Charles Baker issued an Executive Order "To Promote the Testing and Development of Highly Automated Driving Technologies."[70] The Order convened a special working group on autonomous vehicles headed by the Massachusetts Department of Transportation (MassDOT). The main task of the group will be to advise the legislature regarding any legislation necessary to "protect the public welfare."[71] The Order further established that the working group and MassDOT will issue guidance to municipalities to allow testing activities. The Order specifies that such guidance must include a process by which MassDOT must approve companies prior to testing, and obtain a memorandum of understanding (MOU) between the testing company, MassDOT, and any municipality or agency whose roadways would be used.[72]

Massachusetts already has an established hub of driving automation technology including the Massachusetts Institute of Technology (MIT) and several robotics companies. Recently, Singapore-based nuTonomy (an MIT spin-off) announced that it plans to test and develop driving automation technology on public roads in the Boston area.[73]

Very recently, Massachusetts has shown increasing interest in regulating new mobility innovations. For example, ride-hailing services (TNCs) will be subject to a new 5-cent per ride fee.[74] Potentially more impactful, the legislature has introduced a bill that would impose a per-mile fee on automated vehicles, require them to be zero-emission vehicles, and disallow

[69] UT HB 373 of 2016.
[70] Mass.gov, Executive Order No. 572, by His Excellency Charles D. Baker, Governor. "To Promote the Testing and Deployment of Highly Automated Driving Technologies." Oct. 20, 2016.
[71] Ibid.
[72] Ibid.
[73] Pete Bigelow. "Coming to Streets of Boston: nuTonomy's Autonomous Renault." Car and Driver. Nov. 22, 2016.
[74] David Ingram. "Massachusetts to tax ride-hailing apps, give the money to taxis." *Reuters.* Aug 19, 2016.

them from travelling over a mile without a human inside. nuTonomy has strongly opposed this bill.[75]

## 3.10 OTHER STATES

Most U.S. states have not addressed driving automation technology in legislation, regulation, or formal policy. In these states, the rules governing testing and deployment of automated vehicles are limited to the rules that govern all on-road vehicles.[76] As such, public testing and demonstrations of driving automation systems have been acknowledged in a several locations without formal approval.

In some cases, technology developers have worked cooperatively with governing agencies or public officials without a formal framework. In other cases, governing agencies are oblivious or disinterested in public testing activities. States that do not have a formal regulatory framework but are known to host notable development activities include Washington, Texas, and Pennsylvania.

[75] Dylan Martin. "Why a Proposed Mass. Bill Could 'Snuff Out' Autonomous Vehicle R&D." *BostInno*. Jan 26, 2017.
[76] Bryant Walker Smith. "Automated Vehicles Are Probably Legal in the United States." *Texas A&M Law Review*, Volume 1, Issue 3. 2014.

# 4 U.S. STATE AND LOCAL PUBLIC-PRIVATE PARTNERSHIPS

This chapter details public-private efforts in the development of automated and connected vehicle technology that do not directly involve legislation or regulation.

## 4.1 CARNEGIE MELLON UNIVERSITY

Carnegie Mellon University (CMU) has played an outsized role in the recent advancements of automated vehicle technology. CMU's Tartan Racing led the team that won the 2007 DARPA urban challenge. Much of the technology and expertise developed in this project was used to lay the foundations of Google's self-driving car program. More recently, the transportation network company (TNC) Uber acquired a number of AI and robotics experts from University staff after establishing a partnership with CMU and opening a nearby research facility.[77] Carnegie Mellon continues to excel in automotive robotics R&D through the CMU National Robotics Engineering Center.[78] CMU also performs federally-funded research projects through the University Transportation Center (UTC) Technologies for Safe and Efficient Transportation (TSET) program.[79]

## 4.2 COLORADO ROADX

RoadX is a Colorado DOT initiative that focuses on using cutting-edge research and innovations to provide transportation systems solutions. Spurred by the RoadX initiative, CODOT has partnered with private sector partners including Panasonic, HERE, and Otto to demonstrate and utilize connected and automated vehicle systems.[80]

[77] Reuters. "One Year After Announcing Pact, the Uber-Carnegie Mellon Partnership is Stalled." *Fortune*. March 21, 2016.
[78] CMU NREC http://www.nrec.ri.cmu.edu/.
[79] CMU UTC-TSET, http://utc.ices.cmu.edu/utc/utc-tset-projects.html accessed Nov. 2016.
[80] Colorado DOT, RoadX, https://www.codot.gov/programs/roadx.

## 4.3 CONTRA COSTA TRANSPORTATION AUTHORITY GOMENTUM STATION

The decommissioned Concord Naval Weapons Station is now being utilized as a connected and automated vehicle technology testbed, called GoMentum Station.[81] The 5,000 acre facility features 20 miles of abandoned roads—featuring bridges, tunnels, railroad crossings and other infrastructure. The facility has been used by Honda, Apple, and others.[82] Only 40 miles north of Silicon Valley, this is a very convenient facility to test automated vehicle technologies. However, the facility may be only temporary. The long-term general plan for the facility is for mixed-use redevelopment. The use of this site for vehicle testing is now considered temporary by Memorandum-of-Understanding with the city of Concord.[83]

## 4.4 LOCAL MOTOR'S OLLI PILOT DEPLOYMENTS

U.S.-based Local Motors developed an automated shuttle called *Olli*. The shuttle is using cloud-based cognitive computing to analyze information from its 30 sensors. Insight from that analysis will be used by Local Motors in its development process to refine future version of Olli to meet passenger needs and local preferences.[84]

In addition, passengers will be able to interact naturally with Olli via speech, asking, for example, how the vehicle works and information about the destination and other points of interest. The shuttle uses GPS and lidar for navigation, has a 12-person capacity, and a top speed of around 15 mph.[85]

In the summer of 2016, a pre-pilot deployment of Olli took place on public roads in National Harbor, MD. In these early stages, the shuttle is taking passengers and a Local Motors engineer is present at all times in the vehicle, but ultimately the shuttle will not require in person supervision.[86] Local Motors is also in talks with communities and transit agencies, including

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[81] GoMentum Station. http://gomentumstation.net/ accessed November 2016.
[82] Alex Heath. "Inside the abandoned military base where Apple wants to test its top-secret car." *Business Insider*. August 14, 2016.
[83] City of Concord. MOU, July 7, 2015. http://cityofconcord.org/pdf/citygov/agendas/council/2015/0707/6A.pdf.
[84] Local Motors. "Olli." June 16, 2016. https://localmotors.com/posts/2016/06/local-motors-debuts-olli-first-self-driving-vehicle-tap-power-ibm-watson/.
[85] Ibid.
[86] Ibid.

Miami-Dade County, Las Vegas, as well as Berlin, Copenhagen and Canberra, for pilot deployments of the Olli shuttles.[87]


FIGURE 7: LOCAL MOTORS OLLI

## 4.5 MICHIGAN CONNECTED VEHICLE ENVIRONMENT

Southeast Michigan has been the center of DSRC connected vehicle research and development since the establishment of the original U.S. DOT Connected Vehicle Test Bed.[88] Since establishment in 2007, the original testbed been expanded and updated with the latest DSRC technologies, but multiple partners and stakeholders have worked to leverage the federal facilities to develop a permanent self-sustaining connected vehicle environment.

MDOT, along with several public and private partners, have been developing and deploying DSRC technology in Michigan for several years now. Over one hundred DSRC RSUs have been installed around southeast Michigan.[89] The Michigan Connected Vehicle Environment is made up of several individual (but related) projects, as described below.

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[87] Rob Lever. "Olli, a 3D printed, self-driving minibus, to hit road in US." Phys.org. June 16, 2016.
[88] The U.S. DOT Connected Vehicle Test Bed Program is discussed supra section 2.1.
[89] Lindsay VanHulle. "Southeast Michigan navigates smart roads, but financing remains uncertain." Crain's Detroit Business. June 26, 2016.

## SOUTHEAST MICHIGAN TEST BED

The U.S. DOT's Southeast Michigan Test Bed has been in operation since 2007, and has been continually updated as DSRC standards are refined. The test bed is open for developers to leverage standardized infrastructure to develop DSRC-based applications. The test bed has about 50 RSU installations in multiple locations in Oakland County.[90] An additional 17 RSUs have been deployed in the "urban canyon" environment in downtown Detroit.[91, 92]

## ANN ARBOR CONNECTED VEHICLE ENVIRONMENT

The U.S. DOT and partners launched the Connected Vehicle Safety Pilot Model Deployment Project in Ann Arbor, Michigan, in 2012. The project collected data from over 2,800 vehicles and 25 roadside units. The project concluded in 2014. However, the U.S. DOT is supporting transitioning the deployment to an ongoing connected (and eventually automated) vehicle environment.[93] The8 Ann Arbor Connected Vehicle Environment is envisioned as a key component in a larger Southeast Michigan Connected Vehicle Environment—which also includes the U.S. DOT Southeast Michigan Test Bed, described above.

## MDOT CONNECTED VEHICLE INFRASTRUCTURE DEPLOYMENT

In addition to assisting with deployment and operation of U.S. DOT-supported testbeds, MDOT is utilizing its own DSRC infrastructure to develop and deploy V2I applications. The initial pilot applications include:

- Work Zone Warning/Management
- Red Light Violation Warning
- Road Weather Management
- Pavement Condition Measurement

[90] Bettisworth et al. "Status of Dedicated Short-Range Communications Technology and Applications: Report to Congress." U.S. DOT Volpe, ITS JPO. FHWA-JPO-15-218. July 16, 2015.
[91] Ibid note 89.
[92] The U.S. DOT Test Bed program is also discussed *supra* section 2.1, page 2, as related to the U.S. DOT Connected Vehicle program.
[93] University of Michigan Mobility Transformation Center http://www.mtc.umich.edu/deployments/connected-ann-arbor

### AMERICAN CENTER FOR MOBILITY

The state of Michigan has purchased the 335-acre site of the de-commissioned Willow Run General Motors plant for development of the American Center for Mobility (ACM). The state has committed $20 million overall to the purchase and development of a connected and automated vehicle testing and development center on the site. The project is estimated to cost $80 million in overall construction costs. ACM held a groundbreaking ceremony on November 21, 2016, but the project will need additional funding commitment for completion.[94]

## 4.6 OHIO SMART MOBILITY CORRIDOR

The Ohio Smart Mobility Corridor on U.S. 33 consists of 35 miles of four-lane, limited access highway between Dublin and East Liberty, northwest of Columbus. The highway will be equipped by the Ohio Department of Transportation (ODOT) with high-capacity fiber optic cable to instantaneously link researchers and traffic monitors with data from embedded and wireless sensors along the roadway. The Smart Mobility Corridor is a key component of the state's new Smart Mobility Initiative, a collaborative effort between ODOT, the Ohio Department of Public Safety, Wright-Patterson Air Force Base, Case Western Reserve University, University of Cincinnati, University of Dayton, Wright State University, The Ohio State University, Transportation Research Center (TRC), and Ohio Turnpike and Infrastructure Commission.[95] In addition, the TRC has announced plans to spend $100 million to upgrade the facility to support research on autonomous vehicles.[96] The state of Ohio with Ohio State University have pledged $45 million to fund the new TRC SMART (Smart Mobility Advanced Research and Test) Center.[97]

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[94] The Detroit News. "Willow Run sold for $1.2M for driverless testing site." Nov. 6, 2016.
[95] Ohio.gov. "Smart Mobility Corridor to Become Ohio's First "Smart Road."
[96] http://www.toledoblade.com/Automotive/2016/12/18/Ohio-eyes-self-driving-trucks-cars-tests-Transportation-center-seeks-100M-upgrade-to-do-research-on-autonomous-vehicles.html
[97] http://www.trcpg.com/blog/2017/01/27/transportation-research-center-inc-trc-announces-new-smart-mobility-advanced-research-test-center-45-million-new-infrastructure-expansion-test-connected-driverless-vehicles/

## 4.7 STANFORD UNIVERSITY

Stanford University has been at the forefront of automated vehicle development since at least 2005, when a team led by Stanford's Artificial Intelligence Laboratory (SAIL) won the DARPA Grand Challenge. SAIL is now affiliated with Toyota in an effort to develop AI driver assistance.[98]

## 4.8 UNIVERSITY OF MICHIGAN

The University of Michigan Transportation Research Institute (UMTRI) was a key partner in the Connected Vehicle Safety Pilot Model Deployment (SPMD) project. UMTRI continues to be involved with the continuing Ann Arbor Connected Vehicle Environment, and other projects including the University of Michigan Mobility Transformation Center (MTC).

The MTC is a public-private partnership to support research and development of automated vehicles. MTC and UMTRI are currently working to transition the infrastructure installed for the Ann Arbor Connected Vehicle SPMD project into a sustained connected vehicle environment with over 9,000 equipped vehicles.


FIGURE 8: UNIVERSITY OF MICHIGAN MOBILITY TRANSFORMATION CENTER MCITY TEST FACILITY

The MTC also researches institutional and socioeconomic implications of connected and automated vehicles. A critical component of MTC is Mcity, a large-scale testing facility constructed specifically to test and refine connected and automated vehicle systems. Mcity's four-plus miles of roadway allows testers to repeatedly test, observe and shape the behavior of connected and

[98] Stanford-SAIL, http://aicenter.stanford.edu/ accessed November 2016.

autonomous vehicles in a way that can't safely be carried out with real-world driving.

MTC is funded through public sources, as well as through industry partnerships and an affiliates program. The 17 industry members of the MTC "leadership circle" have each pledged to contribute $1 million over a three-year period.[99] Additionally, nearly fifty MTC affiliates contribute $50,000 per year. MTC's leadership circle and affiliates are priority to MTC resources and an opportunity to influence the direction of research activities.

The University of Michigan has a particularly close relationship with the Toyota Research Institute (TRI). In 2016, TRI pledged $22 million over four years for research collaborations with the U-M faculty in the areas of enhanced driving safety, partner robotics and indoor mobility, autonomous driving and student learning and diversity.[100]

## 4.9 UNIVERSITY OF ARIZONA UBER PARTNERSHIP

The University of Arizona has partnered with Uber in August 2015 to research camera-lens design to improve imagery used for mapping and safety features.[101] As a result of this cooperation, several Uber test vehicles will be tested in Arizona. Uber will donate $25,000 to UA's College of Optical Sciences for scholarships.[102]

## 4.10 VIRGINIA AUTOMATED CORRIDORS

The Virginia Department of Transportation and the Department of Motor Vehicles have entered into a new partnership with the Virginia Tech Transportation Institute, Transurban and HERE to create the Virginia Automated Corridors. The new initiative will streamline the use of Virginia roads and state-of-the-art test facilities for automated-vehicle testing, certification, and migration towards deployment.[103]

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[99] MTC, Industry Partners, http://www.mtc.umich.edu/partners/industry accessed November 2016.

[100] http://www.engin.umich.edu/college/about/news/stories/2016/august/accelerate-artificial-intelligence-research accessed Nov. 2016.

[101] "University of Arizona, Uber Partner on Autonomous Car Research," Government Technology, August 26, 2015 http://www.govtech.com/applications/University-of-Arizona-Uber-Partner-on-Autonomous-Car-Research.html

[102] Rituparna Sengupta, "Uber partners with University of Arizona to boost mapping technology." *International Business Times*. August 27, 2015.

[103] https://governor.virginia.gov/newsroom/newsarticle?articleId=8526.

Additionally, the University of Virginia Center for Transportation Studies oversees the U.S. DOT FHWA Connected Vehicle Pooled Fund Studies program, described in section 2.1.

## 4.11 VOLKSWAGEN/AUDI TRAFFIC LIGHT INFORMATION

One potential application of DSRC V2X technology as developed by the U.S. DOT is Signal Phase and Timing (SPaT) (as described in section 2.1). SPaT provides drivers with information regarding the timing of signalized intersections. The SPaT application can also be facilitated by cellular technology, and at least one OEM (Audi) has embedded this feature in real-world consumer vehicles.[104] In covered metropolitan areas, Audi's "traffic light information system" uses LTE connectivity to inform drivers waiting at a red light how much time is remaining before the light turns green.[105] The system also provides in-vehicle speed limit information where available.[106]


FIGURE 9: AUDI TRAFFIC SIGNAL INFORMATION DISPLAY

## 4.12 WAZE PARTNERSHIPS

On the connected vehicle front, there may not be a more impactful relationship between connected vehicle systems and ITS as the growing integration between the navigation app, Waze, and public transportation agencies. Waze is a popular smartphone-based connected navigation application used by millions of commuters and travelers in the U.S. and around the globe.

The travel-time and road condition data sourced from this collection of users is extremely valuable to transportation systems managers. Recognizing this,

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104 Traffic Technology Services. http://www.traffictechservices.com/personal-signal-assistant.html.

105 Sam Abuelsamid. "2017 Audis Will Talk to Some Traffic Signals, Kicking Off Vehicle-To-Infrastructure Communications." Forbes. August 16, 2016.

106 Audi. Press Release: Audi announced first vehicle to infrastructure (V2I) service – the new traffic light information system. August 15, 2016.

Waze pioneered the 'Connected Citizens' Program. Agencies can partner with Waze to disseminate information on traffic congestion, road closures, incidents, and more to all Waze (and Google Nav) users—now a substantial percentage of the travelling public. Further, agencies can initiate a 2-way partnership whereby they have direct access to Waze's crowdsourced, probe-vehicle traffic data.[107] Waze now has over 100 public-sector partners exchanging data.[108]

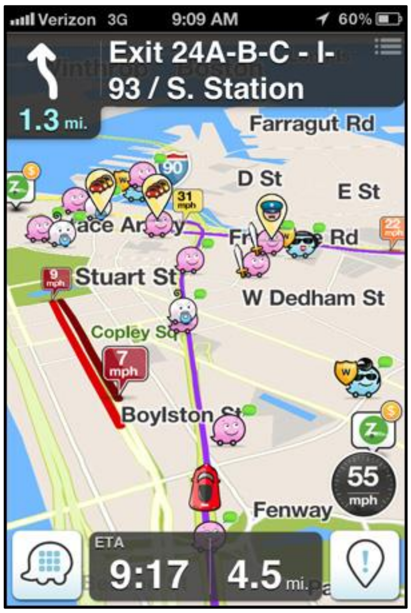


FIGURE 10: WAZE SMARTPHONE NAVIGATION APP CAN INCORPORATE INFORMATION SUBMITTED DIRECTLY FROM TRANSPORTATION AGENCIES THROUGH WAZE'S CONNECTED CITIZENS PROGRAM

[107] Waze. https://wiki.waze.com/wiki/Connected_Citizens_Program.
[108] GISuser. "Waze Connected Citizens Program Celebrates 100th Partner." Oct. 10, 2016.

# 5 EUROPE

There are multiple complimentary efforts to coordinate the deployment of cooperative intelligent transportation systems (C-ITS) and vehicle automation across the European Union. The legal basis for the development of a trans-European transport network (TEN-T) was adopted in 2013, and includes specific provisions for C-ITS. The TEN-T guidelines set a framework for development until 2030.[109] Additionally, the European Commission has initiated an automated and connected vehicle working group under the GEAR 2030 Project. This group will advise the Commission on potential regulatory actions and investments to facilitate the beneficial adoption of connected and automated vehicles.[110]

This chapter provides an overview of key projects regarding C-ITS and driving automation across Europe.

## 5.1 AMSTERDAM GROUP

The Amsterdam Group includes the key stakeholders who have the means to jointly develop and deploy cooperative ITS in Europe.[111] It consists of four umbrella organizations:[112]

- **Car 2 Car Communication Consortium (C2C-CC)**, a non-profit industry group for the accelerated deployment of C-ITS.[113]
- **Conference of European Directors of Roads (CEDR)**, the Road Directors' platform for cooperation and promotion of improvements to European transport infrastructure[114]
- **Association Européenne des Concessionnaires d'Autoroutes et d'Ouvrage à Péage (ACECAP)**, the European Association of Operators of Toll Road Infrastructures[115]

[109] EU. Core Network Corridors Progress Report. 2014.
[110] European Commission. http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8640.
[111] https://amsterdamgroup.mett.nl/home/default.aspx.
[112] Ibid.
[113] https://www.car-2-car.org/index.php?id=22.
[114] http://www.cedr.fr/home/.
[115] http://asecap.com/index.php?lang=en#.

- **Polis**, a network of European cities and regions cooperating for innovative transport solutions[116]

The Amsterdam Group, along with a number of publically funded research and development efforts, supports deployment of C-ITS as outlined in the C-ITS Deployment Platform as adopted by the European Commission (Figure 11).

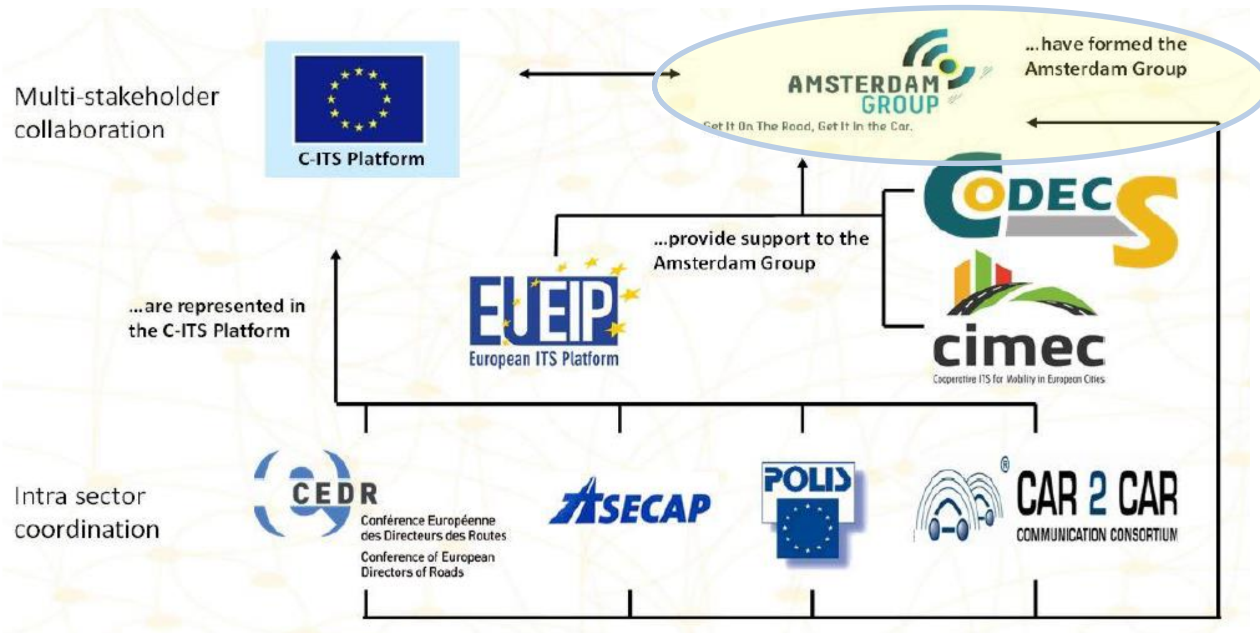


FIGURE 11: THE AMSTERDAM GROUP IS AN ALLIANCE OF PUBLIC AND PRIVATE SECTOR STAKEHOLDERS[117]

## 5.2 C-ITS PLATFORM OF THE EUROPEAN COMMISSION

The Platform for the Deployment of Cooperative Intelligent Transport Systems in the European Union (C-ITS Platform) was created by the European Commission services (DG MOVE) to support the emergence of a common vision across all actors involved in the C-ITS value chain across the EU. The C-ITS platform has gathered insight from public authorities, vehicle manufacturers, suppliers, service providers, telecomm companies, and other stakeholders.[118] Per the C-ITS deployment platform, a series of “day-1” (first phase), and “day 1.5” (later phases) services have been identified to include the following:

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[116] http://www.polisnetwork.eu/.
[117] Image source: EU. Core Network Corridors Progress Report. 2014.
[118] EU C-ITS Platform. Final Report. January 2016.

TABLE 3: C-ITS DEPLOYMENT PLATFORM SERVICES[119]

| "Day 1" Services | "Day 1.5" Services |
|---|---|
| Emergency Electronic Brake Light | Parking Information and Management |
| Emergency Vehicle Approaching | Electric Vehicle Charging Info |
| Slow/Stationary Vehicle | Smart Routing |
| Traffic Jam Ahead | Zone Access Control |
| Hazardous Condition Notification | Vulnerable Road User |
| In-vehicle Speed Limit | Cooperative Collision Risk |
| Probe Vehicle Data | Motorcycle Approaching |
| Shockwave Damping | Wrong-way Driving |
| Signal Violation | Loading Zone Management |

### C-ROADS

C-Roads is an open platform created by the European Commission and member states to develop harmonized specifications for C-ITS with regard to the EU C-ITS Platform recommendations.[120] All member states and independent projects pursuing C-ITS deployment are encouraged to join C-Roads to ensure broad interoperability across the continent. The European Commission has urged C-Roads to start developing interoperability validation tests by autumn of 2017.[121]

## 5.3 ADAPTIVE (FP7)

AdaptIVe is a largescale (€25 million) automotive research project co-funded by the European Union under the 7th Framework Programme (FP7),[122] Grant Agreement no. 610428.[123] The AdaptIVe consortium includes 28 automakers,

[119] Source: Berndt et al. "State-of-the-Art-Analysis of C-ITS Deployment." Deliverable D2.2. EU Horizon 2020, Cooperative ITS Deployment Coordination Support (CODECS). Jan 2016. pp. 67.

[120] http://www.c-roads.eu/.

[121] European Commission. "A European strategy on Cooperative Intelligent Transportation Systems, a milestone towards cooperative, connected and automated mobility." Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Nov. 30, 2016.

[122] FP7 also included two other projects extensively focused on automated and connected vehicle systems: interactive, and HAVEit. Both projects are now complete.

[123] AdaptIVe Project Brochure.

parts-suppliers, and other stakeholders.[124] The project is subdivided into several subprojects, including:[125]

- Evaluation of legal framework (Lead: Daimler)
- Human-vehicle integration and collaborative automation (Lead: Volvo)
- Automation in close-distance scenarios (Lead: Ford)
- Automation in urban scenarios (Lead: Centro Ricerche Fiat [FCA])
- Automation in highway scenarios (Lead: Volkswagen)

A critical deliverable of the AdaptIVe project was a classification and glossary document describing the scope of automated vehicle systems.[126] The project team built eight demonstration vehicles for use by test-subject drivers to help evaluate the relationships between automated vehicle systems and human drivers.[127] The project did not include any deployment activities, but the knowledge gained will be utilized in subsequent deployment-focused projects. AdaptIVe will conclude research with a final event in Aachen, Germany in June 2017.[128]

## 5.4 HORIZON 2020

Horizon 2020 is the eighth EU Research and Innovation program with nearly €80 (approx. $85 billion) of funding available over 7 years (2014 to 2020).[129] Over €6 billion ($6.5 billion) of this will be dedicated to transportation research.[130] The first 2-year work program of Horizon 2020 included several relevant work areas, including:[131]

- MG.3.5-2014. Cooperative ITS for safe, congestion-free and sustainable mobility
- MG.3.6-2015. Safe and connected automation in road transport

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[124] Ibid.
[125] Not all projects described herein directly result in real-world deployment. However, due to the integrated nature of EU FP7, and for reasons of completeness, this report has attempted to include all EU FP7 projects that contribute to a broad goal of connected and automated vehicle deployment.
[126] Bartels, Eberle, and Knapp. "Deliverable D2.1: Systems Classification and Glossary." AdaptIVe. June 2, 2015.
[127] AdaptIVe D1.8 Demonstrator Vehicles, abstract.
[128] https://www.adaptive-ip.eu/index.php/events.html
[129] Horizon 2020, http://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020.
[130] Horizon 2020, Smart, Green and Integrated Transport, http://ec.europa.eu/programmes/horizon2020/en/h2020-section/smart-green-and-integrated-transport.
[131] Horizon 2020, Work Programme 2014 – 2015.

- MG.7.1-2014. Connectivity and information-sharing for intelligent mobility

Several projects have been awarded within these work areas, including the following:

### HIGH PRECISION POSITIONING FOR COOPERATIVE ITS APPLICATIONS (HIGHTS)

HIGHTS will research improving accuracy in vehicle positioning by combining GNSS and on-board sensing and infrastructure-based wireless communication technologies (e.g., Wi-Fi, ITS-G5, UWB tracking, Zigbee, Bluetooth, LTE, etc.) to produce advanced, highly-accurate positioning technologies for C-ITS. Proof-of-concept systems developed in the project will combine infrastructure devices, reference vehicles, communication between road users and offline processing, and will be evaluated under real conditions at TASS' test site in Helmond.[132]

### SAFE AND CONNECTED AUTOMATION IN ROAD TRANSPORT (SCOUT)

SCOUT aims at identifying pathways for an accelerated adoption of safe and connected high-degree automated driving. International trends and emerging research will be closely monitored and reflected in the strategy development process. The results will be discussed with policymakers, stakeholders and the general public.[133]

### VISION INSPIRED DRIVER ASSISTANCE SYSTEMS (VI-DAS)

VI-DAS research and innovation in computer vision and machine learning will introduce vision-based sensing capabilities to vehicles, and enable contextual driver behavior modelling. VI-DAS will study real crashes in order to understand patterns and consequences of driver-assistance technologies. VI-DAS will also address legal, liability and emerging ethical aspects because with such technology comes new risks, and justifiable public concern.[134]

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[132] http://hight s.eu/.
[133] CLEPA/SCOUT, http://clepa.eu/eu-projects/safe-connected-automation-road-transport-scout-project/.
[134] http://cordis.europa.eu/project/rcn/204771_en.html.

### AUTOMATION AS ACCEPTED AND TRUSTFUL TEAMMATE TO ENHANCE TRAFFIC SAFETY AND EFFICIENCY (AUTOMATE)

The vision of AutoMate is a novel driver-automation interaction and cooperation concept to ensure that automated driving systems are commercially deployed to the greatest public benefit. This concept is based on viewing and designing the automation as the driver's cooperative companion or teammate. The top-level objective of AutoMate is to develop, demonstrate and evaluate the "TeamMate Car" concept as a major enabler of highly automated vehicles. The corresponding innovations will be integrated and implemented on several car simulators and real vehicles to evaluate and demonstrate the project progress and results in real-life traffic conditions.[135]

### ADAPTIVE ADAS TO SUPPORT INCAPACITATED DRIVERS MITIGATE EFFECTIVELY RISKS THROUGH TAILOR MADE HMI UNDER AUTOMATION (ADAS&ME)

ADAS&ME will develop adapted Advanced Driver Assistance Systems (ADAS) that incorporate driver state, situational context, and adaptive interaction to automatically transfer control between vehicle and driver. The work is based around seven provisionally identified use-cases for cars, trucks, buses, and motorcycles. The anticipated outcome is the successful fusion of the developed elements into an integrated driver-state monitoring system to support driving automation at various levels. The system will be validated with a wide pool of drivers under simulated and real road conditions.[136]

### MULTI-SOURCE BIG DATA FUSION DRIVEN PROACTIVITY FOR INTELLIGENT MOBILITY (OPTIMUM)

OPTIMUM will establish a scalable, distributed architecture for the management and processing of multisource big-data, enabling continuous monitoring of transportation systems needs, and proposing proactive decisions and actions. OPTIMUM's goals will be achieved by incorporating and advancing state of the art in transport and traffic modeling, travel behavior analysis, sentiment analysis, big data processing, and predictive analysis. The proposed solution will be deployed in real-life pilots in order to realize challenging use cases in the domains of proactive improvement of transport

[135] http://cordis.europa.eu/project/rcn/204767_en.html.
[136] http://cordis.europa.eu/project/rcn/204764_en.html.

systems quality and efficiency, proactive charging for freight transport, and C-ITS integration.[137]

### Enhanced Real Time Services for an Optimized Multimodal Mobility Relying on Cooperative Networks and Open Data (TIMON)

The main objective of TIMON is increasing the safety, sustainability, flexibility and efficiency of road transport systems by taking advantage of cooperative communication through a web-based platform and mobile application. The application will deliver information and services to drivers, businesses, and other transportation system stakeholders in real-time. The project intends to conclude with the design of two validation environments: a testbed site, and another located in an (inter)urban area.[138]

### Research On Alternative Diversity Aspects for Trucks (ROADART)

The main objective of ROADART is to investigate and optimize the integration of C-ITS communication units into trucks. Due to the size of a truck-trailer combination, the architecture approaches investigated for passenger cars are not sufficient. The ROADART project aims to demonstrate road safety applications for systems under critical conditions in a real environment, like tunnels and platooning of several trucks driving close behind each other. Besides evaluation on component and system level, the complete system will be evaluated on the Dutch Integrated Test Site for Cooperative Mobility (DITCM), consisting of a 7 km stretch of highway instrumented test roads.[139]

### Cooperative ITS for Mobility in European Cities (CIMEC)

European highways authorities are relatively knowledgeable and supportive of C-ITS. However, the greatest benefits are expected through the more complex and fragmented city context, which is much less understood. CIMEC focuses especially on this urban C-ITS context. The principal output will be a roadmap for urban deployment of C-ITS which has been validated against

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[137] http://www.optimumproject.eu/.
[138] http://www.timon-project.eu/.
[139] http://roadart.eu/.

user needs and technology maturity, captured in meaningful project descriptions.[140]

### OPEN SOCIAL TRANSPORT NETWORK FOR URBAN APPROACH TO CARPOOLING (SOCIALCAR)

SocialCar's main objective is developing a new communication network for sharing information of car-pooling integrated with existing transport and mobility systems.[141]

### MANAGING AUTOMATED VEHICLES ENHANCES NETWORK (MAVEN)

The MAVEN project will develop infrastructure-assisted platoon organization and negotiation algorithms. These extend and connect vehicle systems for trajectory and maneuver planning and infrastructure systems for adaptive traffic optimization. Additionally, MAVEN will include a user assessment and the development of a roadmap for the introduction of vehicle-road automation to support road authorities in understanding changes in their role and the tasks of traffic management systems.[142]

### 2016 - 2018 WORK PROGRAMME

The second 2-year work program (2016 – 2018) included a specific call for multiple automated road transport (ART), including:[143]

- ART-01-2017: ICT infrastructure to enable to transition towards road transport automation
- ART-02-2016: Automation pilots for passenger cars
- ART-03-2017: Multi-brand platooning in real traffic conditions
- ART-04-2016: Safety and end-user acceptance aspects of road automation in the transition period
- ART-05-2016: Road infrastructure to support the transition to automation and the coexistence of conventional and automated vehicles on the same network

[140] http://cimec-project.eu/.
[141] http://socialcar-project.eu/.
[142] http://cordis.europa.eu/project/rcn/204151_en.html.
[143] Horizon 2020, Work Programme 2016 – 2018.

- ART-06-2016: Coordination of activities in support of road automation
- ART-07-2017: Full-scale demonstration of urban road transport automation

The intent of this call is to support near-term introduction of level 3 driving automation for passenger cars, and truck platooning.[144] Already, hundreds of individual projects have been awarded under this call (though it is too early for significant results).[145]

### COOPERATIVE ITS DEPLOYMENT AND COORDINATION SUPPORT (CODECS)

The CODECS project is a EU-wide effort to coordinate C-ITS deployment across Europe.[146] In addition to serving as a communication and coordination platform for ITS stakeholders across the public and private sectors, CODECS has published information research reports, including an extensive analysis of C-ITS deployment efforts across Europe.[147]

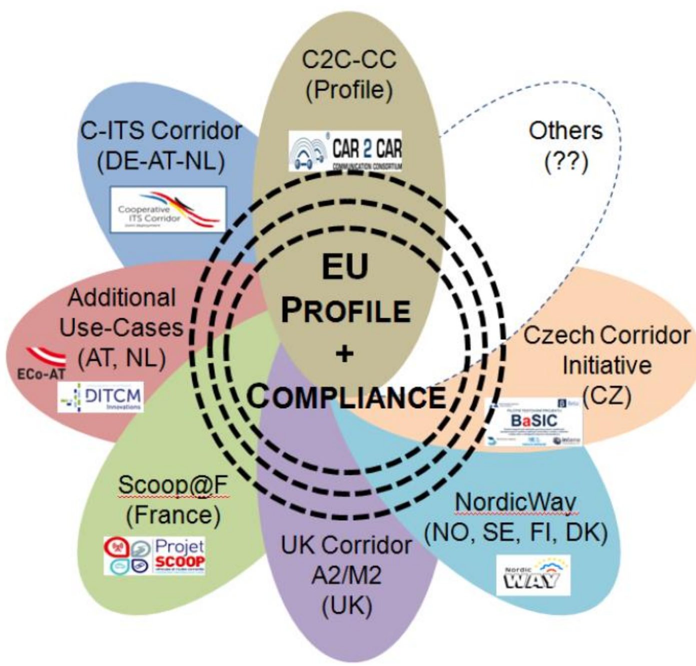


FIGURE 12: INTERNATIONAL EU INTEROPERABILITY PROFILE BY CODECS[148]

[144] Ibid.
[145] CORDIS, http://cordis.europa.eu/projects/home_en.html.
[146] CODECS, http://www.codecs-project.eu/index.php?id=5.
[147] Berndt et al. "State-of-the-Art-Analysis of C-ITS Deployment." Deliverable D2.2. EU Horizon 2020, Cooperative ITS Deployment Coordination Support (CODECS). Jan 2016.
[148] Image source: Ibid.

## 5.5 THE AUSTRIA/GERMANY/NETHERLANDS C-ITS ECO-AT CORRIDOR

This cross-national European ITS Corridor is envisioned to introduce deployment-level C-ITS technologies in the real world. The project is designed to phase-in various applications over time. The initial applications will be *construction warning* and *probe vehicle data for traffic management*. These were chosen for the potential to deliver end-user benefits even in a day-one environment of limited roadside devices and equipped vehicles. The planning phase of the project is scheduled to conclude in March 2017, after which time the project will be put out to bid.[149, 150] The success of this project is dependent on extensive coordination between national governments, standards organizations, and pan-European coordination efforts.[151]

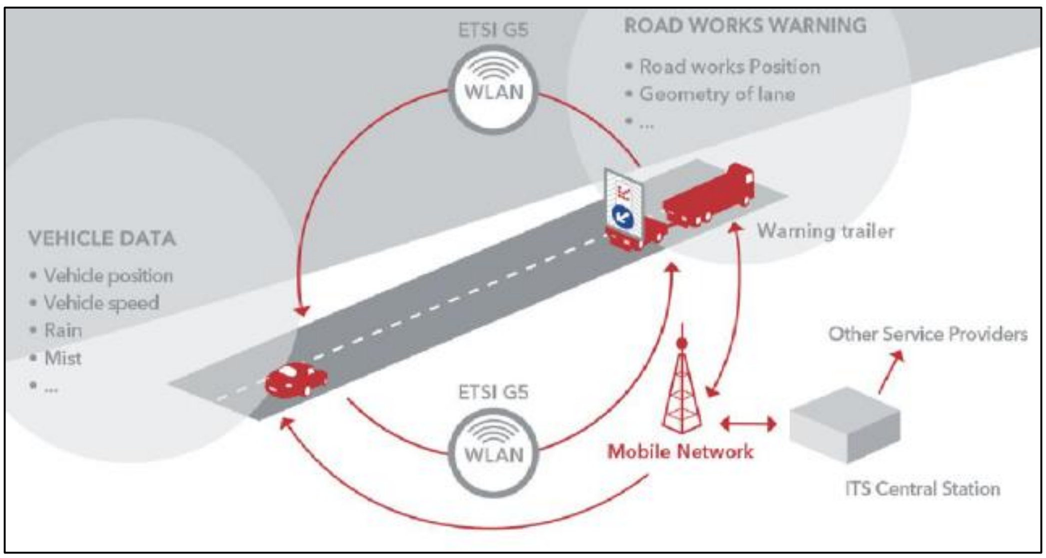


FIGURE 13: INITIAL APPLICATIONS IN AUSTRIA/GERMANY/NETHERLANDS C-ITS CORRIDOR[152]

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[149] ECO-AT Factsheet, http://eco-at.info/downloads-206.html.
[150] Bot, Leitzke, and Harrer. "Smart Mobility: The Cooperative ITS Corridor is Deploying the Future. http://c-its-korridor.de/data/pdf/Intertraffic%20C-ITS%20presentation.pdf.
[151] Berndt et al. "State-of-the-Art-Analysis of C-ITS Deployment." Deliverable D2.2. EU Horizon 2020, Cooperative ITS Deployment Coordination Support (CODECS). Jan 2016. pp. 18-26.
[152] Image source: Ibid.

## 5.6 FRANCE

### SCOOP@F

The SCOOP@F project intends to deploy 3,000 V2X-equipped vehicles and deploy RSUs along over 1,200 miles of roads.[153] Vehicles will be equipped with sensors to detect events such as wheel-slip and emergency braking maneuvers, which will be transmitted to road operators via V2I. Road operators can also transmit warnings to drivers via in-vehicle signage. The list of potential driver-warning events includes:[154]

- Slippery road
- Animal on road
- Human presence on road
- Obstacle on road
- Stationary vehicle
- Accident
- Emergency brake
- Traffic-jam ahead

SCOOP@F phase 1 was active 2014-2015. SCOOP@F phase 2 began in 2016, and is scheduled to conclude in 2018. Phase 2 has also involved partners from Austria, Spain, and Portugal.[155]

### NAVLY PILOT

In September 2016, Navya launched a partnership in the city of Lyon, with Keolis (the transit operator of that metro area), and Sytral (the transit authority of the Lyon metro region) to experiment automated electric public transit. The so-called Navly service uses Navya ARMA shuttles that will run on a 1-mile route with 5 stops in the Confluence sustainable district. The route is free of traffic lights, crosswalks, and intersections. The shuttles will have an average speed of 15km/h (9.3 mph) and will serve the route at a ten-minute frequency.

[153] https://ec.europa.eu/inea/en/connecting-europe-facility/cef-transport/projects-by-country/multi-country/2014-eu-ta-0669-s.
[154] Berndt et al. "State-of-the-Art-Analysis of C-ITS Deployment." CODECS. Jan 2016. p. 29.
[155] Ibid Note 153.

During the one-year period of the project, an operator will be on board of the shuttles to collect data.[156]

## 5.7 CZECH REPUBLIC

The Czech Republic has approved an ITS action plan that outlines the deployment of C-ITS services through 2020, with eventual adoption of automated driving with a 2050 time-horizon. C-ITS deployment in the Czech Republic is planned to proceed over a series of five stages. Stage 1—including probe vehicle data and in-vehicle signage—is now in the process being implemented.[157]

## 5.8 NORDICWAY

NordicWay is a C-ITS corridor project between Finland, Sweden, Norway and Denmark. The project will develop a V-shaped corridor linking Oslo, Gothenburg, Copenhagen, Stockholm, and Helsinki. NordicWay is focused on demonstrating the concept of C-ITS via cellular 3G and 4G/LTE communication, and will involve about 2,000 equipped vehicles. NordicWay applications will consist of safety-related traffic information (SRTI) services and probe-vehicle data. Partners in the NordicWay project are listed in Table 4.

TABLE 4: NORDICWAY PARTNERS AND ROLES[158]

| Partner State | Finland | Sweden | Norway | Denmark |
|---|---|---|---|---|
| **Service Provider/OEM** | HERE | Scania, Volvo Cars, Kapsch | Volvo Cars | N/A |
| **Traffic Data Provider** | Finnish Transport Authority/Infotripla | Ericsson, Swedish Transport Authority | Vegvesen | Danish Road Authority |
| **Traffic Management/Road Authority** | Finnish Road Authority | Swedish Transport Authority | Vegvesen | Danish Road Authority |

[156] NAVLY. Press Release: Navya and Keolis join forces to create Navly, the very first public transportation service operated by an autonomous electric vehicle. Sept 2, 2016.
[157] Berndt et al. "State-of-the-Art-Analysis of C-ITS Deployment." CODECS. Jan 2016. pp. 34-35.
[158] Berndt et al. "State-of-the-Art-Analysis of C-ITS Deployment." CODECS. Jan 2016. p. 31.

## 5.9 COMPASS 4D

Compass4D has installed equipment and implemented cooperative services on almost 300 roadside units and 600 vehicles across the EU. This deployment was spread across seven European cities: Bordeaux, Copenhagen, Helmond, Newcastle, Thessaloniki, Verona and Vigo. Three C-ITS services were investigated: Red Light Violation Warning, Road Hazard Warning, and Energy Efficient Intersection. The EU-funded Compass4D project has officially ended in December 2015. However, the Compass4D consortium and its associated partners have decided to continue operating the C-ITS services (without EU co-funding) for at least one additional year.[159]

## 5.10 NETHERLANDS

### HELMOND SMART MOBILITY LIVING LAB

The Dutch city of Helmond is host to the Smart Mobility Living Lab, a real-world test environment for new mobility solutions. In addition to an instrumented 2 km of public roadway for real-world testing (including a C-ITS network managed by Tass International), shared space is available on the automotive campus for collaborative projects.[160]

### WEPODS PILOT

The town of Wageningen has invested in a pilot project using EasyMile EZ10 self-driving mini-busses (“WEpods”) to shuttle passengers to and from the nearby town of Ede. The shuttles were also used in route around the Wageningen College campus. This research project concluded at the end of 2016.[161]

### DUTCH AUTOMATED VEHICLE INITIATIVE

Another project, the Dutch Automated Vehicle Initiative (DAVI), is sponsoring several research tracts designed to support the eventual structured deployment of high driving automation.[162]

[159] Compass 4D home page, http://www.compass4d.eu/en/home/home.htm.
[160] https://www.drivenbyhelmond.nl/business-portal/helmond-living-lab/.
[161] http://wepods.nl/wepods-rijden-iedere-dinsdag-passagiers-op-wur-campus/.
[162] DAVI. http://davi.connekt.nl/.

## 5.11 UNITED KINGDOM (UK)

The UK Department for Transport (DfK) declared in 2015 that driverless vehicles can legally be tested in the UK without any additional legislation or regulation.[163] The UK and DfT have adopted an active and positive policy regarding automated and connected vehicle technologies, coordinated largely through the DfT Center for Connected and Autonomous Vehicles (CCAV).[164] The CCAV has made available £35 million (about $40 million U.S.) to fund competitive projects to deploy SAE level 4 vehicles with real-world market potential.[165]

Additionally, three deployment-pilot projects funded by Innovate UK are currently ongoing, as detailed below.

### GATEWAY

Taking place in TRL's Smart Mobility Lab in Greenwich, the public and privately funded project will trial and validate a series of different use cases for automated vehicles, including driverless shuttles and automated urban deliveries.[166] Automated vehicles have not yet hit the streets of Greenwich as of November 2016, but much preliminary research and development has been completed.[167]

### UKAUTODRIVE

The UKAutodrive Project kicked off in 2015 with to deploy public demonstrations of connected and automated vehicle technology in the towns of Milton Keynes and


FIGURE 14: A LUTZ PODCAR TO BE DEPLOYED UNDER THE UK AUTODRIVE PROJECT

[163] UK Department for Transport (DfT). "The Pathway to Driverless Cars: Summary Report and Action Plan." February 2015.

[164] https://www.gov.uk/government/collections/driverless-vehicles-connected-and-autonomous-technologies.

[165] Innovate UK Funding Competition: Connected and Autonomous Vehicles 2. https://www.gov.uk/government/publications/funding-competition-connected-and-autonomous-vehicles-2#history.

[166] TRL. https://gateway-project.org.uk/about/.

[167] TRL. https://gateway-project.org.uk/whats-going-on/.

Coventry. Deployment of self-driving pod-cars in pedestrian zones is anticipated for autumn 2017.[168]

On-road vehicles are hoped to be deployed for demonstration in 2018.[169] The on-road vehicles will be larger and more capable than the LUTZ pods. The on-road vehicles will be similar to the "Ultra POD" automated transit system operating within dedicated tracks at Heathrow airport (Figure 15). Additional sensors and advanced software is hoped to allow the PODs to travel reliably in a mixed-traffic public environment.[170]


FIGURE 15: AUTOMATED ULTRA PODS AT HEATHROW AIRPORT

## UK VENTURER

The UK Venturer project has been designed to study the interactions between driving automation systems and their human user (e.g., the 'hand-over' process). The first phase of the project used driving simulators. Results from that phase are planned to be applied to experiments in real vehicles in a controlled environment, and by 2018 on public roads.[171]

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[168] The pods are designed and manufactured by RDM and equipped with autonomous control systems developed by the University of Oxford's Mobile Robotics Group. https://ts.catapult.org.uk/current-projects/self-driving-pods/lutz-pathfinder-automated-pods-project-faq/.

[169] UK Autodrive. http://www.ukautodrive.com/the-uk-autodrive-project/.

[170] Oxbotica. January 2016, http://www.oxbotica.com/news-article/british-manufactured-shuttle-with-oxbotica-autonomous-control-software-joins-gateway-driverless-car-challenge-in-greenwich/.

[171] http://www.venturer-cars.com/

# 5.12 SION, SWITZERLAND NAVYA SHUTTLE PILOT

PostBus, Switzerland's leading public bus operator, has partnered with École Polytechnique Fédérale de Lausanne (EPFL Research Institute) to deploy two Navya eleven-passenger automated shuttles on a fixed route through public areas at up to 12 mph. For the pilot project, each bus will include an attendant, and will be remotely monitored.[172]


FIGURE 16: NAVYA SHUTTLE PILOTED BY POST BUS IN SION, SWITZERLAND[173]

# 5.13 FINLAND SOHJOA EZ10 TRIAL

A project managed through Helsinki Metropolia University of Applied Sciences deployed two EasyMile EZ10 shuttles on low-volume public roads and pedestrian areas in Helsinki.[174] The SOHJOA trial is suspended during winter months but is planned to resume in Spring of 2017.[175]


FIGURE 17: EZ10 SHUTTLE ON THE ROAD IN HELSINKI[176]

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172 EPFL Press Release, "Autonomous Shuttles Start Giving Rides in Sion." June 23, 2016.
173 Source: http://actu.epfl.ch/news/autonomous-shuttles-start-giving-rides-in-sion/.
174 Ben Rosen. "Self-driving buses in Helsinki: did Finland just create a new model?." The Christian Science Monitor. September 1, 2016.
175 EasyMile http://easymile.com/sohjoa-project-finland/.
176 Source: Ibid.

## 5.14 SWEDEN/VOLVO DRIVEME PILOT

Volvo is preparing to deploy SAE level 3 conditionally automated vehicles on public roads in Gothenburg, Sweden. One-hundred (100) Volvo XC90s will be equipped with a beta version of Volvo's 'IntelliSafe Autopilot' automated driving system. The vehicles will be provided to real-world users for typical commuting and daily use.[177]

The Autopilot system will be programmed to work only on a few specific roadways—chosen for simplicity of the driving environment. The routes are mostly divided highways with no pedestrian activity and moderate speeds of about 45 mph.[178] If the DriveMe pilot proceeds as described by Volvo, it will be the first deployment of a level 3 automated driving system on public roads with non-professional test drivers.

## 5.15 GERMANY A9 DIGITAL MOTORWAY TESTBED

Home to Mercedes, BMW, and Volkswagen, Germany is naturally a center of automated and connected vehicle technology development. The first taxonomy concerning vehicle automation was developed by the German federal highway research institute (BASt). The BASt taxonomy became the template for the SAE levels that have become the global default classification system for driving automation.

One project exemplifying Germany's commitment to advanced transportation technologies is the A9 Digital Motorway Testbed in Bavaria. Along the testbed route, the infrastructure will be equipped with various sensors, digital components, and connectivity.[179] The focus is V2X communications, but various measures are being implemented to facilitate connected and automated vehicle technology—such as modification of infrastructure to be better detected by vehicle sensors such as radar and cameras.[180]

Audi (Volkswagen) is taking advantage of the testbed with several projects regarding piloted driving and V2X communications, taking advantage of the

[177] Volvo DriveMe. http://www.volvocars.com/intl/about/our-innovation-brands/intellisafe/intellisafe-autopilot/drive-me.
[178] Ibid.
[179] German Federal Ministry of Transport and Digital Infrastructure. "Dobrindt launches Digital Motorway Test Bed." September 4, 2015.
[180] Volkswagen. "New technologies for piloted driving – Audi participating in "Digital Motorway Test Bed." October 2016.

'LTE-Vehicle (LTE-V)' communications infrastructure provided on the A9. Information from vehicle sensors is fed to a live 3D cloud-based map provided by HERE.[181]

Another German government-funded project, Pegasus, is bringing multiple industry partners together with the goal of field-testing level 4 automated driving systems.[182]

## 5.16 ECALL

Though not typically considered within the scope of C-ITS, the European Union has successfully mandated a relatively simple application of cellular-based connected vehicle technology that is projected to reduce traffic fatalities by at least 4%.[183] The system, 112 eCall, automatically dials Europe's 112 emergency response number in the event of a crash when detected by on-board vehicle sensors. The system automatically routes the call the nearest response center, and sends details of the accident to the rescue services, including the time of incident, the accurate position of the crashed vehicle and the direction of travel.[184] eCall will be mandated on all new light vehicles sold in the EU beginning April 1st, 2018. Member states are obligated to provide infrastructure to support eCall operations across the EU.[185]

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181 Ibid.
182 Pegasus. http://pegasus-projekt.info/de/.
183 European Commission. http://ec.europa.eu/transport/themes/its/road/action_plan/ecall_en.
184 Ibid.
185 European Union. Regulation 2015/758 of the European Parliament and of the Council of 29 April 2015 concerning type-approval requirements for the deployment of the eCall in-vehicle system based on the 112 service and amending Directive 2007/46/EC.

# 6 EAST ASIA

This chapter highlights notable C-ITS and automated driving projects in East Asia, including projects in China, Japan, Singapore, and South Korea.

## 6.1 CHINA

Chinese authorities began getting involved and supporting the development of automated vehicle technology later than their American and European counterparts. They are however making rapid progress with recent activities. In November 2015, Shanghai unveiled a 3.6 km (2 miles) road section for testing self-driving vehicles, the first of its kind in China. Shortly after, similar test areas in the Beijing and Chongqing, and in the provinces of Hebei and Zhejiang were approved by the Ministry of Industry and Information Technology.[186]

### NATIONAL INTELLIGENT CONNECTED VEHICLE TESTING DEMONSTRATION BASE

China's first national-level test center, the National Intelligent Connected Vehicle Testing Demonstration Base, opened in Shanghai in June 2016. The center will support R&D, studies on standards and policy formulation, as well as testing and certifying connected vehicle technology. The center has access to Wi-Fi, LTE-Vehicle (LTE-V), DSRC, and is expected to cover 100 km2 (38.6 square miles) at the end of construction.[187]

The zone will be outfitted with cellular LTE-vehicle and DSRC communications infrastructure, available to partnering automakers and tech developers.[188] China is particularly interested in the use of LTE-V for ITS applications.[189] China and Chinese-based companies (through the China Communications Standards Association [CCSA]) have been innovating connected vehicle technologies using cellular LTE-based technologies.[190] In fact, the A9 Digital Motorway Testbed on Germany's Autobahn[191] uses LTE-

[186] "New facilities for intelligent vehicles", China Daily, last updated on June 13, 2016 http://www.chinadaily.com.cn/business/motoring/2016-06/13/content_25691027.htm
[187] Ibid.
[188] Anna Lu. "Autonomous connected cars on their way." Shanghai Daily. June 8, 2016.
[189] ITS China. http://itsasia-pacific.com/pdf/SongXianghui.pdf.
[190] http://www.astazero.com/wp-content/uploads/2016/06/ITS-for-ASTA-Zero-KEYNOTE-ERICSSON.pdf.
[191] Supra section 5.15 p. 38.

V technology developed by Chinese telecommunication company, Huawei.[192, 193]

Along with the Demonstration Base, two other facilities were unveiled: The Standardization Test and Research Base for Intelligent Connected Vehicles and the Standard Research Center of the China Alliance for Intelligent and Connected Vehicles.[194]

### PARTNERSHIP BETWEEN BAIDU AND CITY OF WUHU

The city of Wuhu signed a five-year agreement in 2016 with Chinese tech-giant Baidu. Baidu plans to gradually introduce automated cars, buses, and vans to selected roads and areas in the city. During the first three years of the trial, the vehicles will not carry passengers.[195] After that three-year period, it is intended that inhabitants of Wuhu will have access to them through a commercial service. After five years, the city expects to introduce self-driving vehicles in mixed traffic with human-driven vehicles on its entire perimeter.[196] Wuhu aims to become the first city in the world to go fully-automated and ban human-driven vehicles.[197]

## 6.2 JAPAN

In November 2015, Japan's Prime Minister made public the goal to provide "transport services using unmanned vehicles" and make possible automated driving on expressways by the 2020 Tokyo Olympics and Paralympics. The Japanese government is expecting that the vehicle technology and road infrastructure will be ready for demonstration tests by 2017.[198]

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[192] Monica Alleven. "Deutsche Telekom, Huawei among those testing LTE-V for next-gen auto tech." Fierce Wireless. July 13, 2016.
[193] Yi Shi. "LTE-V: A Cellular-Assisted V2X Communication Technology." ITU Workshop. 2015.
[194] Ibid.
[195] "Searching for right lane: Baidu hits 'enter' on driverless cars", China Daily, last updated May 18, 2016 http://www.chinadaily.com.cn/business/2016-05/18/content_25337236.htm
[196] Ibid.
[197] Jack Stewart. "Inside China's Plan to Beat America to the Self-driving Car." *Wired*. June 15, 2016.
[198] Shinji Itsubo. "Cooperative ITS Systems in Japan." 23rd ITS World Congress Melborne 2016.

## SIP-ADUS PROGRAM

Connected and automated vehicle technologies are one of the ten themes of the Cross-ministerial Strategic Innovation Promotion Program (SIP), a national project for science, technology and innovation, created in 2014.[199] The Automated Driving for Universal Services (SIP-adus) program[200] (¥2.32 billion or $23.2 million budget in 2015) funds research and development of automated driving systems and next-generation urban transportation infrastructure.

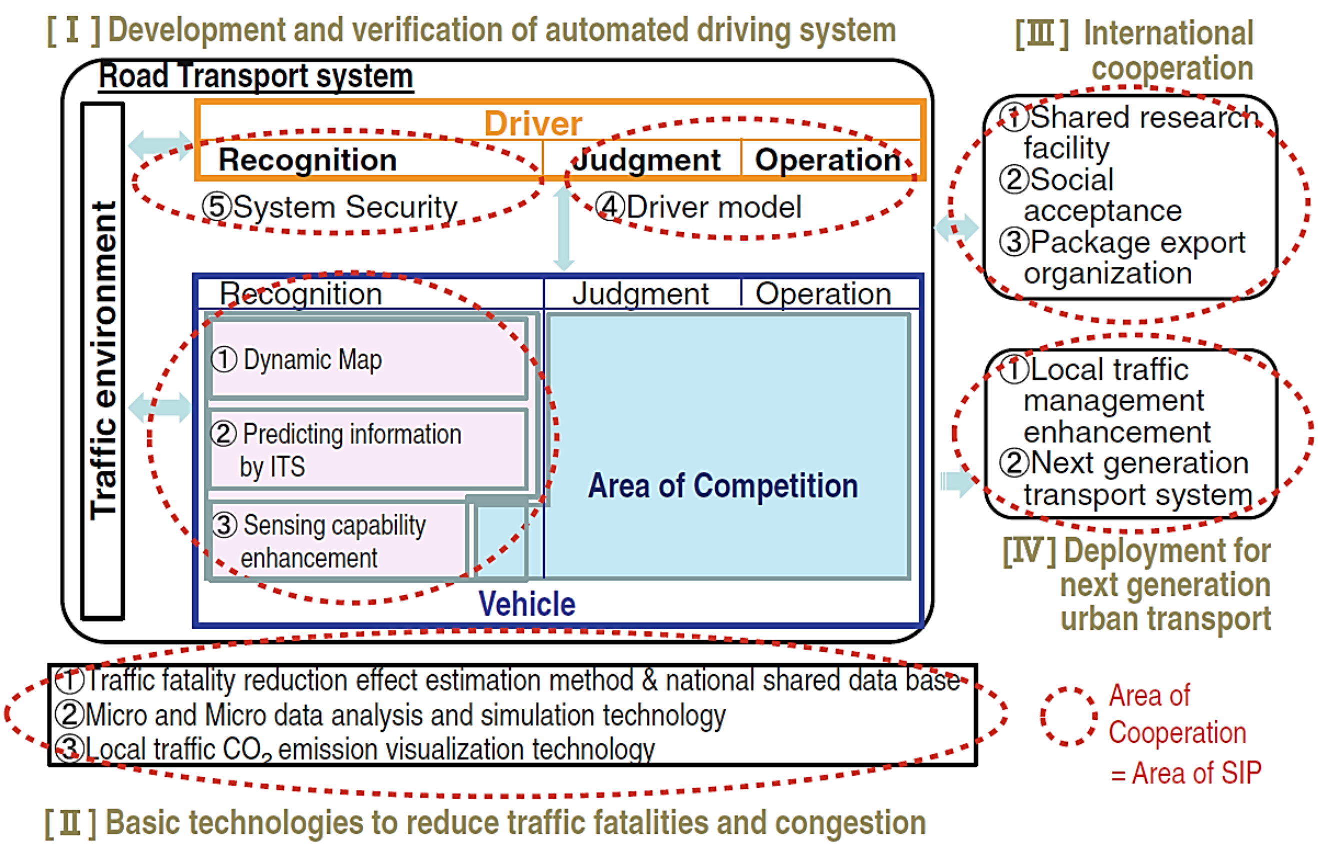


FIGURE 18: IMPLEMENTATION STRUCTURE OF JAPAN'S SIP-ADUS PROGRAM[201]

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[199] Yamamoto, Takumi "Automated Driving Activities in Japan," *in Road Vehicle Automation 2*, Meyer, G.; Beiker, S. (Eds.), 2015.
[200] http://en.sip-adus.jp/
[201] Ibid note 199

The goals of SIP-adas are to reduce the number of annual traffic fatalities from 4,400 in 2013 to 2,500 or fewer by the year 2018 and drastically reduce traffic congestion.[202] The SIP-adus program finances activities in four main categories:[203]

- Development of automated driving systems, which includes: dynamic mapping, technologies for generating prediction data, development of sensors, human factors, and security
- Technologies for reducing traffic accident fatalities and reducing traffic congestion
- Fostering international cooperation[204]
- Deployment of next-generation mass transit.

More than 15 companies participate in this program, including automotive manufacturers (Toyota, Nissan, Honda), suppliers (Denso, Hitachi, etc.), mapping companies, road infrastructure companies.[205]

The overall structure of the SIP-adus program is shown in Figure 18. The red broken-line circles highlight areas targeted by the program, in which automotive manufacturers will cooperate with one another. The light blue area represents the area of competition among manufactures, not covered by the SIP-adus program.[206]

## 6.3 SINGAPORE

The nation-state of Singapore is one of the wealthiest cities on the planet. The island's advanced economy and strong central government allow opportunities for ambitious large-scale projects. Singapore has several initiatives intended to create the most advanced transportation network in the world.

[202] "What is the Cross-ministerial Strategic Innovation Promotion Program (SIP)?", Cabinet Office, Government of Japan website, accessed November 21, 2016 http://www8.cao.go.jp/cstp/panhu/sip_english/5-8.pdf
Factsheet on the Automated Driving System program, Cabinet Office, Government of Japan website, accessed November 21, 2016, http://www8.cao.go.jp/cstp/panhu/sip_english/30-33.pdf

[203] http://en.sip-adus.jp/rd/h27/project.html

[204] Annual international SIP-adus workshop: http://en.sip-adus.jp/evt/workshop2016/

[205] Ibid.

[206] Ibid.

## ELECTRONIC ROAD PRICING (ERP)

Since 1998, Singapore has had the world's most sophisticated urban congestion charging scheme that targets only segments of roads heavily congested and applies prices to those road segments based on operating speed.[207] The city-state now aims to have world's first GNSS urban congestion pricing scheme by 2020. Until now, Singapore has used a tag and beacon system that is non-standard and rather dated now. The new electronic road pricing (ERP) system using GNSS technologies will be based on distance, time, location, and vehicle type.[208]

## CENTRE OF EXCELLENCE FOR TESTING AND RESEARCH OF AUTONOMOUS VEHICLES - NTU

In August 2016, Singapore's Land Transport Authority (LTA) and JTC Corporation (Singapore's state agency for industrial infrastructure development), in partnership with Nanyang Technological University (NTU), launched the Centre of Excellence for Testing and Research of Autonomous Vehicles - NTU (Cetran).[209] The center will lead the development of testing requirements for automated vehicles and will have a 5 acre test circuit with roundabouts, slopes, and an area with simulated rainfall. Research at Cetran is scheduled to start mid-2017, led by NTU.[210]

## ONE-NORTH DISTRICT TEST-BED

Singapore's Land Transport Authority is particularly interested in automated vehicles as a first-and-last mile solution for commuters between a mass transit station and their home or work place. LTA believes that such a solution would increase the usage of the mass transit systems, reduce overall traffic congestion and vehicle emissions. In August 2016, LTA partnered with

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[207] Robert Arnold et al. "Reducing Congestion and Funding Transportation Using Road Pricing in Europe and Singapore." American Trade Initiatives, FHWA. December 2010.
[208] Scott Wilson. "Singapore will have the world's first GNSS urban congestion pricing scheme by 2020." D'Artagnan Blog. March 18, 2016.
[209] Press release, Nanyang Technological University, August 1, 2016, http://media.ntu.edu.sg/NewsReleases/Pages/newsdetail.aspx?news=8dee5f22-436e-40d9-89ca-3bcb053be33c
[210] Traffic Technology Today. "Singapore launches autonomous vehicle testing center." August 8, 2016.

Delphi and nuTonomy to test on-demand automated transportation concepts in the One-North district test-bed.[211]

One-North is part of the Singapore Autonomous Vehicle Initiative (SAVI), a joint partnership formed in 2014 between LTA and the Agency for Science, Technology, and Research (A*STAR) to provide a technical platform for industry R&D and testing of automated vehicle technology. If these trials are successful, the projects could be developed limited commercial services by 2018-2019 and into full-scale mobility solutions across Singapore after 2020-2022.

As part of their self-driving technology tests, nuTonomy started picking up passengers in six modified Renault Zoe and Mitsubishi i-MiEV in late August 2016. A few weeks later, the startup announced a partnership with ride-hailing company Grab, to give its future users the possibility to hail a self-driving car. Additionally, Delphi is developing a cloud-based mobility-on-demand software (AMoD) suite and conducting its trial on six self-driving Audi SQ5.[212]


FIGURE 19:NUTONOMY TEST VEHICLE IN SINGAPORE[213]

## SMRT – 2GETTHERE PARTNERSHIP

Singapore transport operator SMRT and automated shuttle manufacturer 2getthere have been working together since 2010. In April 2016, they partnered to form 2getthere Asia. The goal of this partnership is to trial 2getthere's third-generation *Group Rapid Transit* (GRT) vehicle in Singapore

[211] LTA. Press Release: "LTA to Launch Autonomous Mobility-on-Demand Trials." August 1, 2016.
[212] Ibid.
[213] Image: http://www.motortrend.com/news/nutonomy-launches-self-driving-car-service-singapore/.

by the end of 2016 and assess the feasibility of such a system on the island.[214, 215] This new type of vehicle has a 24 passengers capacity. 2getthere is developing applications for fully-dedicated right-of way and mixed-traffic situations. The international development subsidiary of SMRT has acquired a 20% stake in 2getthere.[216]

### DSRC Technical Specifications

In October 2016, the Info-communications Media Development Authority (IMDA) of Singapore issued technical specifications for DSRC operating in the 5.9 GHz frequency band.[217] The document details IMDA's decisions to adopt the suite of IEEE Wireless Access Vehicular Environment (WAVE) standards. This effort was done in collaboration with the Land Transport Authority (LTA). IMDA has pledged to continue to monitor the global DSRC standardization effort (EU-US ITS Task Force, comprising ETSI, IEEE and ISO) closely, and regularly update Singapore's standards in accordance. The IMDA technical specifications for DSRC will take effect on October 1, 2017 to allow device manufacturers to make the necessary adjustments to comply with the requirements.[218]

## 6.4 South Korea

South Korea is the fifth-largest auto manufacturing country in the world, and thus is a significant stakeholder in the development of connected and automated vehicle technology. In September 2015, South Korea announced that the national government would contribute efforts towards developing and integrated connected and automated transportation system.[219] South Korea permitted testing of automated vehicles on select public roads in 2015, and expanded the scope of available roads in 2016.[220]

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[214] "SMRT and UTC Investment", 2getthere press release, June 30, 2016, accessed November 22, 2016 http://www.2getthere.eu/smrt-and-uts-investment/

[215] As of February 2017, we could not find any evidence that this has happened.

[216] Ibid.

[217] Info-Communications Media Development Authority, "Technical Specification for Dedicated Short-Range Communications in Intelligent Transport Systems (Operating in the 5.9 GHz Frequency Band), Oct. 6, 2016.

[218] Ibid.

[219] Jeong Eun Ha, Officer for Innovation, Technology and Science. "Autonomous Vehicle Industry in Korea." Sept. 24, 2015.

[220] South Korea Ministry of Land, Infrastructure and Transport. Press release: ROK to facilitate Autonomous Vehicle Testing on Public Roads. October 5, 2016.

South Korea has embarked on a year-long pilot of a next-generation Cooperative Intelligent Transportation System (C-ITS) project in preparation for the 2018 Winter Olympics.[221] The pilot is taking place on a 87.8 km route between Sejong and Daejon.[222] It is hoped that rapid response times, combined with the ability of V2X-capable cars to see around corners or through obstacles beyond the driver's line of sight, will prevent accidents while significantly improving traffic flow and reducing CO2 emissions. The C-ITS technology uses the DSRC-WAVE standards, similar to C-ITS projects in the EU and U.S.[223]

[221] ITS International. "NXP and eSSys to provide ITS technologies for Korean C-ITS pilot project." July 26, 2016.
[222] Smart Cities World. "Intelligent transportation technology pilot for South Korea." July 21, 2016.
[223] Ibid.

# 7 OTHER REGIONS

## 7.1 AUSTRALIA

In August 2016, Australia published its National Policy Framework for Land Transport Technology, containing policy principles and a 2016-2019 action plan. The Australian government aims to support the deployment of connected and automated vehicle technology through policy leadership, supporting investment in digital infrastructure, providing access to transportation data, creating a supportive regulatory environment, and investing in R&D and trials.[224]

In November 2016, Australian transports ministers agreed pursue a legislative reform program in order to allow the safe and legal operation of conditionally automated vehicles before 2020, leading to the eventual deployment of highly and fully automated vehicles. In preparation for this process, the National Transport Commission (NTC) released a policy paper on Regulatory Reforms for automated road vehicles[225] and a discussion paper on national guidelines for automated vehicle trials.[226]

South Australia became the first Australian state to allow testing automated vehicles on its roads in March 2016. Companies looking to trial technologies need to submit plans for approval to the Transport and Infrastructure Ministry.[227]

New South Wales leads the Cooperative Intelligent Transport Initiative (CITI),[228] a C-ITS testing facility in the Illawarra region, south of Sydney. CITI is a large-scale C-ITS testbed dedicated to heavy vehicles. It operates with 60 vehicles and three intersections equipped with DSRC. Several V2X

[224] Commonwealth of Australia, National Policy Framework for Land Transport Technology, August 2016 http://transportinfrastructurecouncil.gov.au/publications/files/National_Policy_Framework_for_Land_Transport_Technology.pdf

[225] National Transport Commission, Regulatory Reforms for Automated Road Vehicles, November 2016 https://www.ntc.gov.au/Media/Reports/(32685218-7895-0E7C-ECF6-551177684E27).pdf

[226] National Transport Commission, National guidelines for automated vehicle trials. Discussion paper, November 2016 http://www.ntc.gov.au/Media/Reports/(FEAAC3B0-8F38-2C35-5FBC-4968034E6565).pdf

[227] "SA becomes first Australian jurisdiction to allow on-road driverless car trials," Department of Planning, Transport and Infrastructure, Press release, March 31, 2016 http://dpti.sa.gov.au/news?a=255933

[228] http://roadsafety.transport.nsw.gov.au/research/roadsafetytechnology/cits/citi/index.html

applications are being researched within CITI, including: intersection collision warning, forward collision warning, heavy braking ahead warning, traffic signal phase information, speed limit information.[229]

Government, industry and university partners launched the Australian Driverless Vehicle Initiative (ADVI) in July 2015 to collaborate on research, inform the development of national policy, legislation, regulation and operational procedures.[230]

## 7.2 NEW ZEALAND

New Zealand legislation does not explicitly require a driver present in the vehicle for it to be used on the road. Therefore, testing of self-driving vehicles without human drivers can be carried out on all public roads. The New Zealand Transport Agency is offering companies wishing to test automated vehicle technology information about the approved testing process and obligations according to the New Zealand legislation.[231]

Whereas testing in New Zealand faces less barriers than in other parts of the world, the country is investigating potential challenges with deployment. Precisely, New Zealand imports all its vehicles and relies on adopting standards from any of the four major standard setting regimes: Europe, Japan, United States, and Australia. In order to avoid importing cars with diverging standards concerning automated and connected vehicle technology, the government is considering whether to limit imports to only one jurisdiction. In addition, there are concerns about the limited coverage of GNSS satellite-based augmentation systems in New Zealand and the vehicle features depended on that.[232]

Austroads, the association of Australian and New Zealand road transport and traffic authorities, has a CAV program that is supporting various projects. In 2015-2016, the program focused on:[233]

- Supporting the development of Cooperative ITS
- Assessment of safety benefits of C-ITS and automated vehicles

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[229] Ibid.
[230] http://advi.org.au/
[231] Ibid.
[232] Ibid.
[233] Austroads' CAV Program http://www.austroads.com.au/drivers-vehicles/connected-and-automated-vehicles/projects

- Assessment of key road operator actions to support automated vehicles
- Investigation of potential registration & licensing issues due to the introduction of automated vehicles

In 2017, Austroads aims to develop operational frameworks for C-ITS, as well as the operation, licensing, and registration of automated vehicles.[234]

## 7.3 UNITED ARAB EMIRATES

Dubai's 2030 goal is to make 25% of all trips within the city driverless, as announced in 2016 by Vice President and Prime Minister of the United Arab Emirates.[235] The Masdar personal rapid transit (PRT) system, comprising ten vehicles (Figure 20) with a 6-person capacity, opened to the general public in 2010 and has transported two million passengers since its launch, as of November 2016. The 2getthere PRT service runs on a dedicated route of 1.4 km (1 mile) with only two 2 stations, the North Car Park and the Masdar Institute for Science and Technology.[236]

FIGURE 20. 2GETTHERE PERSONAL RAPID TRANSIT

[234] Ibid.
[235] 2getThere. http://www.2getthere.eu/smrt-and-uts-investment/.
[236] 2getThere. http://www.2getthere.eu/projects/masdar-prt/.