
# HISTORY OF INTELLIGENT TRANSPORTATION SYSTEMS

## 2023 Update

U.S. Department of Transportation

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**16. Abstract**
ITS capabilities have matured significantly over the past 25 years since the ITS Joint Program Office was created, and this document celebrates the advances in this field and explore its exciting future, while also serving as a guide for future ITS research programs. Our nation stands now at the cusp of revolutionary changes to our transportation system, including connected and automated vehicles, making it a particularly apt time to look back at the history of ITS and reflect on what we can learn to help shape the future.

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# EXECUTIVE SUMMARY

At this moment, our nation stands at the cusp of some of the most revolutionary changes to our transportation system in decades. Connected and automated vehicles are closer than ever to being part of our everyday world, and the decisions we make regarding these and other advanced technologies could profoundly affect the future of transportation. As we move toward a more intelligent and connected transportation system, it is important to reflect on the history of the field, recognize lessons learned, identify trends and their historical implications, and acknowledge both the successes and the failures that have brought us to our current point in the evolution of intelligent transportation systems (ITS).

> **"The history of ITS was greatly influenced by specific champions who pushed the branding of ITS and created a much-needed consciousness of what ITS can do.**
>
> —Scott McCormick, President of the Connected Vehicle Trade Association

ITS is an operational system of various technologies that, when combined and managed, improve the operating capabilities of the overall system. According to a recent national survey conducted by the University of Iowa, there are very large gaps in the public's knowledge about ITS.[1] Many people have little knowledge of "formal" ITS, yet they benefit from its existence every day. ITS technology is the phone application that you use to determine how long to wait before walking to catch the next bus. It is your car's advanced braking system that monitors wheel speed and adjusts brake pressure

1 http://www.sltrib.com/news/business/2015/09/10/survey-shows-big-gaps-in-knowledge-about-auto-safety-tech/

so that you can stop quickly and safely without losing control of your vehicle. ITS allows you to drive at highway speeds through toll collection kiosks, and helps you determine the exact location and delivery date of your online purchase with just a few clicks of the mouse. Moreover, ITS technologies (such as GPS use for mapping and positioning) and operational advancements (such as coordinated traffic management centers) allow quick and efficient mobilization of responders to an incident by providing real-time traffic, route, weather, and even hazardous material information across agencies.

Without question, ITS technology has made transportation safer and more efficient. While many think improving our nation's transportation system solely means repairing aging infrastructure or building new roads, the future of transportation lies not only in these efforts, but also increasingly in implementing ITS technologies. The benefits of ITS are wide reaching and applicable to urban and rural populations; commuters and commercial truck drivers; and pedestrians, bikers, and public transportation system users. Building on decades of ITS research and deployments, the very near future will likely include vehicles that can talk to one another and roadside infrastructure to avoid collisions, improve congestion, and recognize environmental benefits. ITS will enable automated vehicles to interact with the transportation system—a concept that has captured the human imagination for decades, and is closer than ever to widespread deployment.

> "We are not just in the transportation business. We are in the quality of life business.

– James Pol, Technical Director, Federal Highway Administration Office of Safety Research and Development

ITS technology has already had a significant impact on the current transportation environment. We are now on the verge of greater benefits and impacts due to advances in technology. For example, connected vehicle technology research indicates that vehicle-to-vehicle safety systems may address up to 80 percent of collision-based accidents where the driver is not impaired. Fully automated vehicles may offer even greater safety benefits. As research, development, and deployment marches on, these advanced solutions will increasingly yield even more mobility, environmental, safety, and other benefits.

Over time, the ITS field has evolved, not only technologically but also in the area of public and private interactions. The relationship between industry and the government has progressed into an essential partnership, which has catalyzed the development of new technologies. This partnership is critical to the success of ITS. This report will highlight both public and private agency investments and advances, often achieved through collaborations between the two.

The United States Department of Transportation (U.S. DOT) Intelligent Transportation Systems Joint Program Office (ITS JPO) produced the update to this report to celebrate the ITS JPO's 30th anniversary. In addition, the ITS JPO wants to highlight the history and future of ITS developments and how these technologies have shaped our current environment and will influence our future.

The *History of ITS* report is organized chronologically, starting with early ITS history (prior to 1980). Each successive chapter covers a one-decade span, from the 1980s to the present day; the final chapter discusses the future of ITS. The chapters explore the socio-economic environment, policy and programs, and research and technology developments specific to each time period.

**Experts from a variety of professional backgrounds were interviewed:**

Total number of interviewees: 32

Interviewees from the public sector: 19

Interviewees from the private sector: 6

Interviewees from associations: 5

Interviewees from academia: 2

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CHAPTER 1

Photo Source: General Motors

# THE EARLY HISTORY

## The Socio-economic Environment

The promise of a future with technologically advanced transportation options has occupied the collective American imagination for decades. The tagline of the 1939-1940 New York World's Fair promised to show visitors "the world of tomorrow." Arguably, the most popular feature was a ride called Futurama in the General Motors Pavilion. Futurama attracted huge audiences; many waited in line for hours to experience possible life in the then-distant future year 1960.

The Futurama ride carried visitors past miniature yet realistic landscapes that focused on what transportation might look like in 20 years. Simultaneously, a narrator described this futuristic utopia forged by sophisticated transportation planning. Highways ran through rural farmland before moving into well-ordered cities. Automated vehicles had radio controls to help them maintain a proper distance from one another.

In 1939, there was no interstate freeway system, and many people did not own a personal vehicle. The audience left this exhibit with new ideas of what was possible and particularly new visions for the future of transportation, setting the stage for a period of incredible transportation advancement.

**Pre-1980**

- ITS was a "champion"-driven vision among public, private, and academic institutions.
- Transportation professionals recognized the limits on surface transportation capacity.
- ITS research during this time focused on specific in-vehicle navigation and route guidance systems.
- Technology was developed opportunistically, and there was little original equipment manufacturer (OEM) interest.

**Futurama 1939 New York World's Fair "To New Horizons" 1940 General Motors:**

https://www.youtube.com/watch?v=-JFgpxYaeJQ

The American car culture began to form during the early 20th century. The first three-colored traffic signal was deployed in 1914, and the first parking meter was installed in 1935. In the 1920s alone, the number of passenger cars registered in the United States nearly tripled, from 8 million to 23 million.[2] Automobile sales slowed during the 1930s and early 1940s, due to the Great Depression and World War II. Around 30 million motor vehicles (cars, trucks, and buses) were registered in 1937.[3] The number of vehicles grew only slightly over the next several years, from about 32 million in 1940 to 33 million in 1946.[4]

After World War II, the United States experienced economic growth and increased land development. Factories, which were previously supplying wartime needs, switched to producing automobiles. Automobile sales accelerated again in the mid-1940s, partly because many middle-class families left cities for the new suburbs. By 1950, the number of registered vehicles had risen to 49 million.[5]

In 1956, Congress passed the Federal-Aid Highway Act, which led to the creation of the U.S. interstate network. The 41,000-mile system was planned to reach every metropolitan area with a population larger than 100,000.[6] Interstates opened up more land for development, and suburbs continued to expand from city edges. By 1960, the number of vehicles on the road totaled nearly 75 million.[7] Over the ensuing decades, as speed and congestion increased, so did the prevalence and severity of collisions.

Throughout the 1950s, commuting standards changed as more workers moved to the suburbs. The suburbanization of retail and the rise of the shopping mall followed the suburbanization of residences. Starting in the 1970s, businesses followed suit. Highways exceeded capacity with people commuting from one suburb to another.

On October 15, 1966, an act of Congress established the United States Department of Transportation (U.S. DOT). Prior to this, the Under Secretary of Commerce for Transportation administered many of the functions that are now associated with the U.S. DOT. Safety had been a recognized automotive issue since the mid-1930s, but government agencies began setting vehicle and highway safety standards starting in the 1960s. Seat belts, padded dashboards, standard bumper heights, and dual braking systems became mandatory for new cars in 1967. Later, standards such as air bags and child car seats were implemented. The Highway Safety Act of 1970 established the National Highway Traffic Safety Administration (NHTSA). Concepts for the use of advanced technologies on the nation's transportation system emerged at this time, but pre-dated a national ITS program. During this early period, the roots of ITS can be seen in research initiatives and deployments undertaken by states and regions, academic institutions, and the automotive industry.

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**2** http://www.ushistory.org/us/46a.asp

**3** Kaszynski, William. *The American Highway: The History and Culture of Roads in the United States.* eBook. Google Books. Page 111.

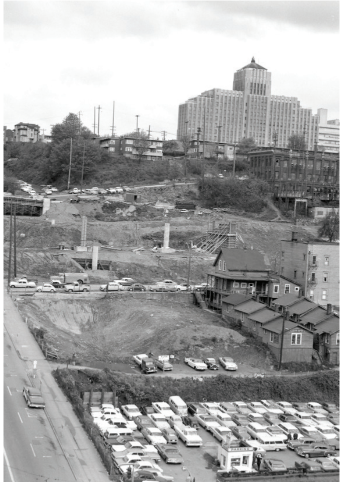
**4** Lukacs, John. A New Republic: *A History of the United States in the Twentieth Century.* eBook. Google Books. Page 109. Rose, Mark H. & Raymond A. Mohl. *Interstates: Highway Politics and Policy Since 1939.* eBook. Google Books. Page 31.

**5** Rose, Mark H. & Raymond A. Mohl. *Interstates: Highway Politics and Policy Since 1939.* eBook. Google Books. Page 31.

**6** http://www.econedlink.org/lessons/projector.php?lid=725&type=educator

**7** http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1623457

Safety, decreased congestion, and improved mobility were the key driving forces behind ITS. The public sector has historically focused more on safety and environmental benefits. Private sector research and development, particularly during these early years, focused more on convenience and mobility. While coming at these various issues and technologies from different places, the two sectors have often converged in their approaches over time, resulting in joint projects and investments that have provided a variety of benefits.



U.S. Interstate Highway construction in Seattle, Washington, in 1963.

Photo Source: Federal Highway Administration

# Research and Technology Developments

## Navigation and Mapping Technologies

U.S. research into proximity beacon navigation started with General Motor's Driver Aided Information and Routing System (DAIR) in the mid-1960s.[8] A car with DAIR could send an emergency message to a service center, including information on road conditions. The system relied on magnets buried at regular intervals along the road (generally between 3 to 5 miles apart) and used binary code to communicate location information. DAIR included a display panel on the car's dashboard that would show warning messages regarding road hazards and had a system that could guide a driver along a pre-determined route. General Motors installed this technology in two 1966 vehicles and tested it at their testing center in Detroit, Michigan. Ultimately, General Motors could not muster the resources necessary to deploy the system. The two DAIR-equipped cars were never tested outside General Motors' facilities.

The DAIR project was closely followed by the Bureau of Public Roads (now the Federal Highway Administration) Experimental Route Guidance System (ERGS) in the late 1960s. ERGS transmitted radio communications between the vehicle and roadside units. Several organizations under contract to the Office of Research and Development of the Bureau of Public Roads, including General Motors and Philco-Ford, investigated the system concept. Several prototype ERGS roadside units were installed at intersections around the eastern United States, including two in Washington, DC.[9] In the 1970s, the project was ultimately discontinued due to the expensive infrastructure required, but similar approaches were deployed during this timeframe in Germany and Japan.

New communications approaches and the development of map-matching algorithms gave rise to alternatives to the proximity-beacon approach. Map-matching algorithms were first developed in the 1970s and supplemented existing technology in early navigation systems. Networks of roads were modeled in a digital map database, in which a particular route could be programmed mathematically. An onboard computer was used to analyze dead reckoning[10] inputs and match the vehicle's path to the programmed routes. Robert L. French developed the first map-matching

**8** http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1623457

**9** *Popular Science*, 1969. https://books.google.com/books?id=GSoDAAAAMBAJ&pg=PA102&lpg=PA102&dq=electronic+route+ERGS+public+roads&source=bl&ots=OfWo7zeEPO&sig=IsGrGCAngWuyD3a7DXqRmKdU5qY&hl =en&sa=X&ved=0ahUKEwjXttiukOfLAhVEqR4KHZ1SDiwQ6AEIQjAJ#v=onepage&q=electronic%20route% 20ERGS%20public%20roads&f=false

**10** Dead reckoning is the process of calculating one's current position by using a previously determined position, and then using estimated speeds, as well as elapsed time and course information, to advance that position (http://www.britannica.com/technology/dead-reckoning-navigation) system, called the automatic route control system (ARCS), in 1971[11]. First developed for a newspaper delivery route, it used map-matching technology paired with real-time route guidance. A pre-recorded voice message played at appropriate points in the route. For this technique to work, the vehicle was generally assumed to follow a predetermined road, but there was uncertainty when the vehicle traveled off-road because there was no way to correct for errors. A second version of ARCS gave route directions visually by using a plasma display panel and simple graphics.

Starting in the 1970s, transit agencies in North America were the first adopters of an early generation of bus automatic vehicle location (AVL) mapping technology using wayside signpost beacons as a location tracking method. Early AVL systems essentially provided simple vehicle position confirmation. One of the first techniques involved burying magnetized strips of metal in the roadbed. As a transit vehicle passed over the magnetized strip, a pickup coil on the vehicle detected a coded pattern, which was used to identify the vehicle location. This system was very costly and required significant maintenance. Present-day AVL systems offer sophisticated real-time vehicle location tracking and schedule monitoring using more advanced technology.


A dynamic message sign alerts drivers of an incident ahead.

Photo Source: https://en.wikipedia.org/wiki/Variable-message_sign#/media/File:MN_Changeable_Message_Sign.jpg

## Loop Detectors

Loop detectors have become the most widely used sensors in incident detection systems. Loop detectors can estimate vehicle speed as well as measure flow and occupancy. Inductive loop detectors consist of one or more loops of wire embedded in the pavement and connected to a control box. When a vehicle passes over or rests on the loop, the change in current flow (or inductance) of the loop indicates the presence of a vehicle. Vehicle detection loops are often used at traffic lights to detect the presence of traffic waiting at the light and are used to activate a traffic control device, thus reducing the green-signal phase time for empty roads.

## Dynamic Message Signs

A dynamic message sign (DMS) is an electronic traffic sign that provides information and warnings to travelers. These signs can be used for a variety of messaging purposes, including informing drivers of traffic congestion, upcoming accidents, roadwork zones, or changing speed limits. First deployed in the 1960s, DMS continue to provide helpful information on the roadways today. The signs have been instrumental in non-traffic-related applications including providing the foundation for the AMBER Alert system, which relays vital child abduction notifications.


Poorly designed and managed freeway entrance ramps can have significant adverse mobility and safety impacts on nearby freeways and arterials.

Photo Source: http://www.greencarreports.com/news/1095932_milan-pays-drivers-to-leave-cars-at-home-take-public-transit

## Ramp Management

The 1950s brought research into ramp management techniques as a potential solution to highway safety concerns. In 1963, the first ramp meters were deployed along Chicago's Eisenhower Expressway. An onsite traffic enforcement officer manually controlled these early meters.[12] Over the next several years, subsequent ramp meters were successfully deployed in Detroit and Los Angeles. In 1967, Los Angeles implemented the first known ramp closure. In 1972, Minneapolis introduced a bus bypass lane at its metered ramp to promote the use of mass transit.[13] Since this

**11** https://www.researchgate.net/publication/3155668_Automatic_route_control_system

**12** http://ntlsearch.bts.gov/tris/ntlc/itsjpo/record28118.shtm

**13** http://ops.fhwa.dot.gov/publications/ramp_mgmt_handbook/manual/manual/1_1.htm time, ramp management strategies have evolved and thrived. Today, ramp metering strategies are commonplace in jurisdictions across the United States and are shown to have safety, mobility, and environmental benefits.

Poorly designed and managed freeway entrance ramps can have significant adverse mobility and safety impacts on nearby freeways and arterials.

## Traffic Management Centers

The first North American traffic management centers (TMCs) were deployed in the late 1960s. The TMC is the hub or center of most freeway management systems. The TMC collects and processes data about the freeway system such as weather, speed, congestion, incidents, and special events. This data is fused with other operational and control data and distributed to stakeholders such as the media, other agencies, and the traveling public. TMC staff use the information to monitor and manipulate freeway operation. TMCs are an operational epicenter where agencies can coordinate their responses to traffic situations and incidents. The role of a TMC often goes beyond the freeway network, functioning as the key technical and institutional hub to bring together the various jurisdictions, modal interests, and service providers. Together, these entities can focus on their common goal of optimizing the performance of the entire surface transportation system.

Integrated traffic management centers are the center of most modern freeway management systems.

Photo Source: Seattle DOT

## Global Positioning Systems

The global positioning system (GPS) consists of a network of satellites that transmit signals to GPS receivers. The signals carry a time code and geographical data that allow users to pinpoint their exact speed, position, and time. GPS was originally designed for military and intelligence purposes during the 1960s, at the height of the Cold War. In the 1980s, GPS was released for use in civilian applications.

During the 1990s, civilian use of GPS became more available and affordable. Today, millions of users rely on GPS to navigate with great accuracy whether on land, air, or sea. Drivers can use in-vehicle portable navigation devices to find the most efficient route, find traffic detours, and even receive traffic alerts or warnings regarding safety camera locations.

GPS-based AVL systems were generally adopted by many transit agencies in the late 1990s. GPS enables geographic information systems (GIS), which store, analyze, and display geographic information. GIS is used to monitor vehicle location, which keeps transit vehicles on schedule and informs passengers of precise arrival times. Mass transit systems use this capability to track rail, bus, and other services to improve on-time performance. This technology also enables efficient response to emergency scenarios.

GPS is an essential element in the future of ITS because it offers increased efficiencies and safety for highways, streets, and mass transit systems. Many new capabilities are possible due to GPS, such as instant carpools that match riders with nearby vehicles in real time.

**Top Photo**: The first hand-held consumer GPS device was the Magellan NAV 1000.

Photo Source: https://timeandnavigation.si.edu/multimedia-asset/magellan-nav-1000-gps-receiver-1988

**Bottom Photo:** This equipment was the basis of a federal experimental emergency response system from 1995. The system was tested in Colorado and relied on GPS data, cellular telephone connections, and map databases. Ford's Remote Emergency Satellite Cellular Unit and General Motor's OnStar superseded this test system.

Photo Source: https://timeandnavigation.si.edu/multimedia-asset/emergency-vehicle-location-system

## Early Mobile Robotics

In the late 1960s, the Defense Advanced Research Projects Agency (DARPA) funded a project at the Stanford Research Institute to create the first mobile robot with the ability to perceive and reason about its own actions. The robot, named Shakey, was designed to perform navigation and exploration tasks using various sensors, range finders, and a TV camera. *LIFE* magazine featured Shakey in a 1970 issue, referring to the robot as the "first electronic person." Shakey was considered a failure at the time for never reaching autonomous operation. However, the project established functional and performance baselines for mobile robots.[14]

Robotics research has been instrumental in the development of many ITS technologies. The navigation, sensory, and exploration functions that mobile robots use have been developed and transferred into technologies such as connected and automated vehicles.

In 1960, an engineering graduate student originally developed the Stanford Artificial Intelligence Laboratory Cart to study the potential of controlling a moon rover from a control station on Earth. Over the next 46 years, the Stanford Cart was reconfigured multiple times to serve in different capacities. In 1979, the Stanford Cart made mobile robotic history when it autonomously traveled across a room filled with chairs. The travel time for this historic feat? Approximately 5 hours.[15]

**14** http://www.dtic.mil/dtic/tr/fulltext/u2/a422845.pdf

**15** http://www.wired.com/2012/02/autonomous-vehicle-history/

CHAPTER 2

# THE 1980s

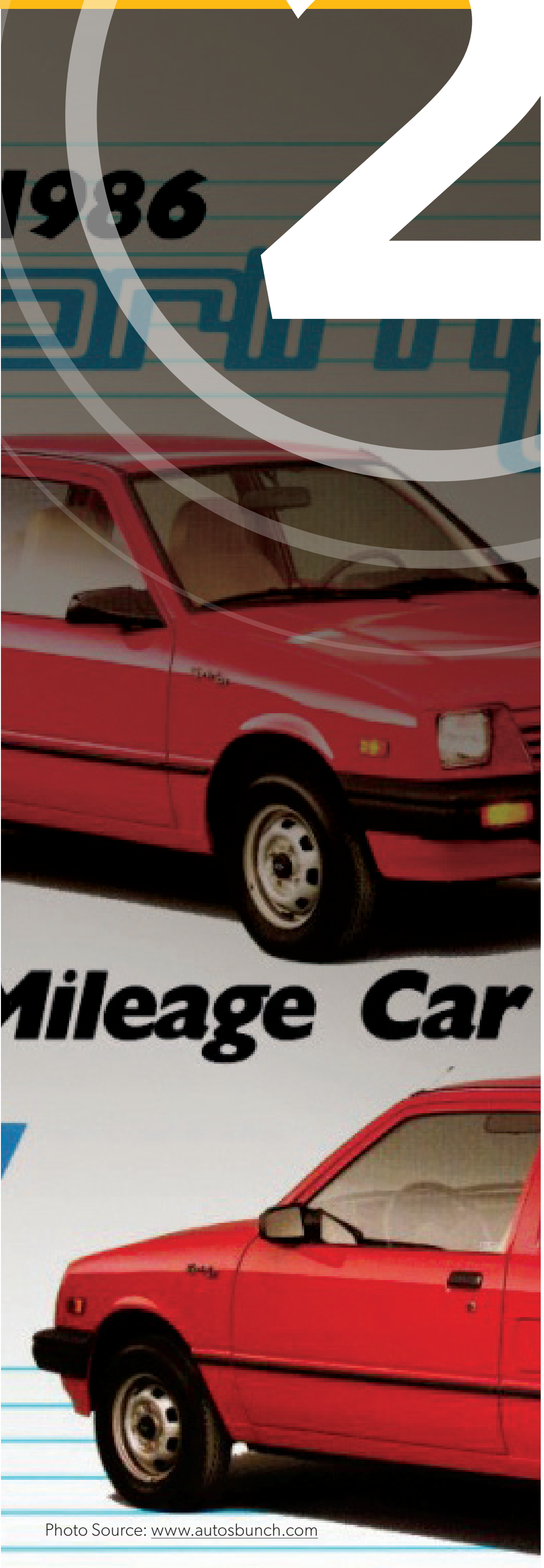


Photo Source: www.autosbunch.com

## The Socio-economic Environment

During the 1980s, major changes appeared to be on the horizon. Legacy transportation programs, long in place, began to appear less suitable for the future, and Americans started to reconsider their relationship to transportation. Safety and environmental concerns became the increasing focus of transportation policy. There were 51,091 highway fatalities in 1980, and gas shortages in the 1970s led to a Congressional mandate that required new vehicles to get a minimum number of miles per gallon of fuel.[16] In addition, widespread concern about air pollution and the environment led Congress to start regulating automobile emissions.

During the 1980s, in the midst of these concerns, technology became cheaper and smarter—and technologies supporting improved traffic management emerged. Government agencies saw new possibilities for information, sensing, communication, and controls technologies to solve the environmental and safety problems associated with transportation. The transportation industry recognized new highway infrastructure-based technologies as a competitive business opportunity that would add value to their products. New technological developments—microprocessors, computers, sensors, new communications technologies, and GPS—were emerging with direct transportation implications.

This decade coined the term intelligent vehicle highway system (IVHS), which described a group of technologies (including information processing, communications, control, and electronics) that connect vehicles to infrastructure to improve the safety and efficiency of transportation systems. During this decade, there was no formal national IVHS program. However, much of the work in the 1980s set the stage for the current and future state and evolution of ITS, and enabled the development and implementation of advanced technologies across transportation areas in subsequent decades.

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**16** http://www.statisticbrain.com/car-crash-fatality-statistics-2/

In 1981, the first commercial car navigation system, the Honda Electro Gyro-Cator, was made available.

Photo Source: http://jalopnik.com/the-first-commercially-available-car-navigation-system-1574754802

## Policy and Programs

Three significant trends were evident in the 1980s:

1. Public interest and state/local organizations formed a coalition to develop new Federal-aid transportation program proposals.
2. In the United States, Europe, and Japan, industry research focused on potential ways to apply new technology to transportation in the form of IVHS concepts.
3. State, federal, and university researchers organized meetings to discuss the potential of advanced technology.

During this decade, several universities started formal research programs focused on advanced technology in surface transportation. The California Program on Advanced Technology for the Highway (PATH)[17] was one of the most visible of these programs. PATH was founded in 1986 as a collaboration between the University of California at Berkeley and the California Department of Transportation (Caltrans), and is still an active and leading-edge research institution.

At the same time, the U.S. DOT funded a modest program of university research and in-house "automated vehicle highway systems" research. The ERGS program started in the early 1970s and evolved into ARCS. ARCS was the first autonomous route guidance system that used an on-board computer with digitized maps, map-matching software, and a dead-reckoning subsystem. The Federal Highway Administration (FHWA) Traffic Systems Division collaborated with several universities on and conducted other small-scale exploratory projects in freeway management, advanced traffic control, computer simulation, and driver information systems. At the same time, visible, well-funded programs in Europe and Japan spurred global interest in the potential of related technology applications.

In a few areas around the United States, "pioneer" applications of advanced technology emerged in major arterial traffic control, traffic conditions information sharing, and electronic tolling. At the end of the decade, industry leaders who were interested in these new technologies organized a series of increasingly formal meetings. This group dialogue evolved into Mobility 2000, formed as an advocacy group in 1989 to represent the new technology perspective in policy formation. Mobility 2000 was predominantly a volunteer activity and had no formal authority. However, it played an important role in bringing together advocates from a variety of institutions, including state and federal governments, industry, consulting, and academia to represent the new technology perspective in policy formation. Mobility 2000 mobilized support for a national IVHS effort and sponsored the first National Leadership Conference on IVHS. The organization was essential in determining a conceptual definition for IVHS and promoting the formation of IVHS America (now called the Intelligent Transportation Society of America, or ITS America), a Utilized Federal Advisory Committee to the U.S. DOT.

**17** Later renamed Partners for Advanced Transit and Highways before combining with the California Center for Innovative Transportation to form the California Partners for Advanced Transportation Technology.

This development paralleled efforts on the part of a coalition of 12 surface transportation interest groups—led by the American Association of State Highway and Transportation Officials (AASHTO) and the Highway Users Federation (HUF)—to consider future broad directions for the Federal-Aid Highway Program, which faced reauthorization in 1991. This included a programmatic approach to developing the role of new technology. The first congressional hearing related to the potential of new IVHS technology was held in 1989, the first step in what would become a key focus of almost all subsequent transportation appropriations bills and areas of interest for Congress and other federal agencies.

# Research and Technology Developments

## Automated Traffic Surveillance and Control System

The Los Angeles Automated Traffic Surveillance and Control System installed in 1984 was the first to integrate vehicle detectors, closed-circuit television, and coordinated signal timing.

## Operation Greenlight

Operation Greenlight was a joint effort between the Illinois Department of Transportation and other regional transportation agencies to reduce vehicle congestion in the region. Operation Greenlight started in 1989 and had two main goals—to reduce demand on the region's existing highway network and to increase capacity.[18] The project relied on input from the private sector, including the different modes of the freight community—trucking, rail, marine terminals, airlines, and freight associations.

## Fuel-Efficient Traffic Signal Management

California's Fuel-Efficient Traffic Signal Management (FETSIM) program started in 1983. At the time, traffic signal retiming was a suggested means of improving traffic operations and reducing fuel consumption and emissions, but few local agencies had been able to fund such an operation. FETSIM was one of the first statewide programs to provide funding, training, and technical assistance to local agencies to retime their signal systems for greater operating efficiency.[19]

During the 11 years that this program was active, over 160 cities and counties retimed 12,245 signals. Retiming these signals reduced vehicular delays by 14 percent, decreased stops by 13 percent, decreased overall travel times by 7 percent, and cut fuel consumption by 8 percent. The FETSIM program also supported a number of research and development activities that improved analysis tools for traffic signal management. These tools were used nationwide, and the FETSIM program served as a model for several statewide signal management programs around the country.[20]

**18** http://www.fhwa.dot.gov/planning/freight_planning/archive/chicago.cfm

**19** http://trid.trb.org/view.aspx?id=288542

**20** http://trid.trb.org/view.aspx?id=451797

**Photo on the Right**: The 12-foot tall DARPA ALV drove through the Colorado hills in 1985 without human intervention.

Photo Source: http://paleofuture.gizmodo.com/darpa-tried-to-build-skynet-in-the-1980s-1451000652

## DARPA Autonomous Land Vehicle


The DARPA-sponsored artificial intelligence demonstrations that began in the 1960s with Shakey resurfaced in the early 1980s with the DARPA Autonomous Land Vehicle (ALV). The ALV was built on an all-terrain vehicle with sensors ranging from video cameras to laser scanners. The ALV contained six racks of computers programmed with algorithms and using images from the rooftop camera to steer safely along the road without need for human assistance. The ALV demonstrations began in 1985 at a speed of 3 kilometers per hour over a 1-kilometer straight road.[21] Over the next 2 years, the ALV was modified to be able to navigate longer courses at faster speeds with varying curves and pavement types, while avoiding obstacles.

## TRANSCOM

TRANSCOM is a coalition of 16 transportation and enforcement agencies in New York, New Jersey, and Connecticut, with the mission of a cooperative, coordinated approach to incident notification, regional incident management, and construction coordination. TRANSCOM was established in 1986 as the Transportation Coordinating Committee for the region to ensure a common approach for developing solutions, including technology-based solutions, to the region's problems. In its early years, TRANSCOM was important for recognizing the institutional dimension to technology development and deployment. Since that time, TRANSCOM's role has expanded to include a multi-agency testbed for implementing ITS technologies.

## National Cooperative Highway Research Program 03-38(1)

The National Cooperative Highway Research Program (NCHRP) project 03-38 (1), "Assessment of Advanced Technologies for Relieving Urban Traffic Congestion," which began in 1987, researched and assessed advanced technologies based on their ability to improve urban traffic operations, including capacity and traffic flow. For the most promising of these technologies and systems, researchers formulated a plan for research, development, testing, and demonstration.

NCHRP 03-38 (1) reviewed traveler information systems, traffic control systems, and automatic vehicle control systems. The study also reviewed urgent steps underway to develop a national IVHS program, concluding that there was an urgent need for a national program for developing, demonstrating, and implementing advanced transportation technologies.[22]

**21** http://www.dtic.mil/dtic/tr/fulltext/u2/a422845.pdf

**22** https://books.google.com/books?id=5o5DPPfnop8C&lpg=PP5&ots=Ks4aSzszKO&dq=Project%203-38(1)&pg=PP5#v=onepage&q=Project%203-38(1)&f=false

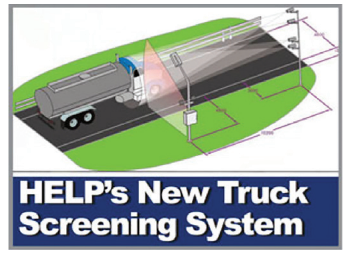
## Heavy Vehicle Electronic License Plate Program

The Arizona and Oregon Departments of Transportation (DOTs) established the Heavy Vehicle Electronic License Plate Program (HELP) in 1984 to conduct research on commercial vehicle weigh-in-motion and automated vehicle identification (AVI) technologies. The program grew into a consortium of U.S. and Canadian federal, state, and local agencies and motor carrier organizations that conducted a multi-state demonstration of truck pre-screening and pre-clearance approaches at weigh stations between Texas and British Columbia, known as the Crescent Demonstration Project.

The HELP Program ultimately led to the creation of HELP, Inc., a non-profit, public/private partnership, and the launch of its PrePass service. Today, PrePass represents North America's largest truck safety pre-clearance service and the nation's largest vehicle-to-infrastructure (V2I) program.[23]

**Benefits of Electronic Screening:**

- Time savings are estimated at 1.5 to 4.5 minutes per bypass.
- Carriers with good safety records will have fewer inspections.
- Weigh station traffic is reduced.
- Inspectors can focus their efforts on high-risk carriers.[24]




A 1984 depiction of a screening site with an electronic license plate reader and automated vehicle identification technology.

Photo Source: http://www.bing.com/images/search?q=heavy+vehicle+ electronic+license+plate+program+ help+in+1984

23 http://www.helpinc.us/

24 http://fresno.ts.odu.edu/newitsd/ITS_Serv_Tech/freight_oper/freight_operations_summary4.html

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# THE 1990s

## The Socio-economic Environment

In 1990, the United States was on the cusp of a technological revolution. The Interstate Highway System, considered the centerpiece of conventional transportation improvement, was complete and new directions to improve transportation were sought as part of the impending reauthorization of the Federal-Aid Highway Program.

> "Surface transportation in the United States is at a crossroads. The mobility we prize so highly is threatened. Many of the nation's roads are badly clogged. Congestion continues to increase, the conventional approach of the past—building more roads—will not work in many areas of the country, for both financial and environmental reasons.
>
> —Intelligent Vehicle-Highway Systems Strategic Plan, prepared by IVHS America (1992)[25]

1991 marked the end of the Cold War and the fall of the Berlin Wall. The United States experienced peace dividends through significant growth in the industrial, transportation, and healthcare sectors. The World Wide Web was invented just before the turn of the decade, and in the United States (as well as in Europe and Japan), attention increasingly focused on the potential of new technical developments both within and outside of transportation. Rapidly improving technology suggested new possibilities for a safer and more efficient transportation system through advances in sensing and computing technologies. This decade's key challenge was how to realize the value of and implement new advances in technology into such a large and multifaceted transportation system.

Dialogue among committed transportation champions and stakeholders brought the concept of IVHS into the mainstream of transportation policy discussions. The 1991 reauthorization of the Federal-Aid Highway Program made a significant

**25** http://ntl.bts.gov/lib/jpodocs/repts_pr/1823.pdf public commitment to institutionalize IVHS. This crucial step established the foundation for the Federal-aid ITS program and the public-private partnerships that have continued to this day. This advancement solidified the role and importance of ITS in maintaining, improving, and growing our transportation systems.

Since its founding, ITS America has grown significantly. Its membership includes public agencies, private companies, and academic and research institutions. ITS America is "dedicated to advancing the research, development, and deployment of Intelligent Transportation Systems (ITS) to improve the nation's surface transportation system."[26] ITS America has been instrumental in many aspects of ITS. They petitioned the Federal Communications Commission to set aside the frequency for dedicated short-range communications, which is now the foundation for connected vehicle technology. The organization also played a key role in the national traveler information system, or 511, by conducting a study that found that over 300 phone numbers just on the east coast of the United States were needed to determine road conditions.

## Policy and Programs

Mobility 2000, the informal interest group of academics, stakeholder groups, and U.S. DOT researchers, had been meeting since the late 1980s and pushed forward the idea that the U.S. DOT needed to engage key players in the broader transportation community. Also informing the group were representatives from the Prometheus Program in Europe. In late 1990, this HUF-led discussion resulted in the creation of the 501 (c) (3) membership association IVHS America. IVHS America, now called ITS America, was founded in 1991 by a few innovative individuals at the National Leadership Conference. AASHTO, the Transportation Research Board (TRB), the Institute of Transportation Engineers, and HUF signed on as founding members. IVHS America's first annual meeting was held in Reston, Virginia, in 1991 and had approximately 500 attendees.

Parallel to the founding of IVHS America in 1991, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) was signed into law by President George H.W. Bush. ISTEA was regarded as the first transportation bill of the post-Interstate era and established policies that recognized the shift in focus from the building of a surface transportation system to the operational management and maintenance of that system and the importance of encouraging the development and application of ITS advanced technologies. ISTEA included a requirement that the U.S. DOT designate a federally utilized advisory committee to provide advice and assistance in the area of IVHS. Soon thereafter, the U.S. DOT designated IVHS America as its federally utilized advisory committee for IVHS, and executed a contract with the new association to carry out specific tasks and provide advice.

ISTEA established an IVHS program with a budget of $660 million and an initial timeframe of 6 years.[27] The program began as a three-pronged effort that fostered the development of ITS through:

1. Basic research and development

**26** http://www.itsa.org

**27** http://ntl.bts.gov/DOCS/ste.html

2. Operational tests that served as the bridge between basic research and full deployment

3. Various technology transfer activities that facilitated the implementation of ITS technologies. There were designated priority corridors that received funding to develop an operations test program.

These test programs focused on research including the development of systems architecture, standards, and protocols for five IVHS user service components (advanced traffic management systems, advanced traveler information systems, commercial vehicle operations, advanced public transportation systems, and advanced vehicle control systems). The legislation also called for the establishment of a program plan to guide and support the development of an automated highway system. The plan would serve as a template for a future fully automated highway system concept that would support and stimulate the improvement of vehicle and highway technologies.

The IVHS program funded a series of operational tests during the early 1990s that blazed the way forward for new systems and technologies. Some of the most notable projects include Automated Highway Systems, TravTek, Pathfinder, Advanced Driver and Vehicle Advisory Navigation Concept (ADVANCE), Guidestar, INFORM, the Denver Smart Bus Project, FAST-TRAC, and HELP.

In February 1994, the U.S. DOT established a Joint IVHS Program Office (JPO) to coordinate intermodal policy in the implementation of the IVHS program. With policy direction from the Office of the Secretary and Modal Administrators, the Joint IVHS Program Office was located within FHWA. The Office provided overall management and oversight of the IVHS program, including those of FHWA, the Federal Transit Administration (FTA), NHTSA, and the Research and Special Programs Administration (RSPA). In the autumn of 1994, the national IVHS program was renamed the Intelligent Transportation Systems (ITS) Joint Program Office, to clarify the multimodal intent.

In 1994, the U.S. DOT officially sanctioned the term "ITS" as a replacement for IVHS, recognizing the multimodal nature of the activity and de-emphasizing the focus on technologies for vehicle guidance.

One key activity of the ITS JPO during this period was to establish a degree of standardization within ITS. In the mid-1990s, the ITS JPO, drawing on aerospace experience, developed and standardized a national systems architecture and standards to promote interoperability and a coordinated national approach. The systems architecture has three layers:

- The communications layer provides for accurate and timely exchange of information between systems.
- The transportation layer defines transportation solutions in terms of the subsystems and interfaces, as well as the underlying functionality and data requirements for each transportation service.
- The institutional layer includes institutions, policies, funding mechanisms, and processes that are required for effective implementation.

The National ITS Architecture provides the framework that ties the transportation and communication worlds together into specific applications. Applications are oriented toward a specific user service—such as traveler information, sign messages, ramp metering, electronic tolling, or vehicle safety systems. In any given setting, ITS are combined with specific real-time agency actions to comprise transportation systems management and operation projects and programs. In addition, ITS technology provides much of the technological heart of the new transportation frontier of vehicle automation and connected vehicles, which provide significant mobility and safety benefits.

The U.S. DOT established the ITS Standards Program in 1996 to encourage the widespread use of ITS technologies in our nation's surface transportation systems. The ITS Standards Program has worked with standards development organizations and public agencies to accelerate the development of open communications interface standards. These standards define how intelligent transportation components and systems interconnect and exchange information to deliver ITS services within a multimodal network. The consistent and widespread use of ITS standards will permit data and information sharing among public agencies and private organizations. Currently, nearly 100 standards have been published and are ready to use in ITS deployments.[28]

In 1996, the U.S. DOT announced three major ITS deployment initiatives—the Metropolitan Model Deployment Initiative (MMDI), the Advanced Rural Transportation System, and the Commercial Vehicle Information Systems and Networks (CVISN) Model Deployment Initiative (MDI). The U.S. DOT selected four locations for the MMDI. The four model deployments were the Seattle Smart Trek, the San Antonio TransGuide, the Phoenix AZTech, and the New York-New Jersey-Connecticut iTravel. Under MMDI, true partnerships between public agencies and private companies formed to create regional transportation management systems that provided improved operations, faster emergency response, and better incident management. Each of the four ITS metropolitan model deployment sites addressed the challenges of developing an integrated, multimodal intelligent transportation infrastructure in different ways, but all the sites focused on a common vision of providing more efficient transportation systems and better traveler information.

> **“There has been enormous value in creating a National ITS Architecture. It has generated a recognized forum for stakeholders to come together and talk about what outcomes they need in order to truly improve our transportation system.**
>
> – Interviewee

First conceived in 1996, CVISN was envisioned as a program through which the necessary open standards and technical framework could be developed to link ITS and commercial vehicle operations (CVO) elements into a single architecture that could be shared by the states participating in the pilot study and ultimately, of course, by all CVO interests in North America. The CVISN Program is a collection of information systems, communications networks, and ITS that support CVO. Through a dedicated CVISN Grant Program, established in 1999, the Federal Motor Carrier Safety Administration (FMCSA), formerly affiliated with FHWA, supports states in the deployment and evaluation of advanced technologies in the program areas of safety information exchange, electronic credentialing, and electronic screening. The CVISN MDI in 1996 demonstrated the technical and institutional feasibility, costs, and benefits of CVISN user services and encouraged further deployment. The initial participants included two prototype states (Maryland and Virginia) and eight pilot states (California, Colorado, Connecticut, Kentucky, Michigan, Minnesota, Oregon, and Washington).

**28** https://www.standards.its.dot.gov/LearnAboutStandards/ITSStandardsBackground

The Transportation Equity Act for the 21st Century (TEA-21) passed in 1997 and retained ISTEA's essential features while boosting highway construction investments. TEA-21 provided a total of $1.282 billion for fiscal years 1998 through 2003 to fund the ITS Program. Of this total, $603 million was targeted for research, training, and standards development; $482 million for metropolitan and rural systems; and $184 million to deploy a commercial vehicle ITS infrastructure.[29,30] TEA-21 moved the U.S. DOT's ITS Program from a moderate research program to a program that both researches and deploys ITS technologies.

In response to the new IVHS priority corridors program, two multi-state coalitions formed to capitalize on the potential of IVHS and corridor systems management. The I-95 Corridor Coalition formed as a partnership of transportation agencies, toll authorities, public safety, and related organizations. Initially, it spanned from the State of Maine to the State of Virginia, but, over time, the I-95 Corridor Coalition successfully expanded down the entire east coast to the State of Florida. Similar alliances formed in other parts of the United States, such as the Gary-Chicago-Milwaukee Corridor Coalition.

Starting in the 1980s and particularly increasing under ISTEA, the transportation sector saw a dramatic growth in earmarking, a practice in which Congress designates funds or resources to a particular project or purpose. While many observers are very critical of earmarks, some were successful for ITS, including FAST-TRAC, Guidestar, and the I-95 Corridor Coalition.

ITS research and deployment today heavily focuses on connected and automated vehicles. This focus is rooted in a range of activities that occurred in the mid-1990s:

- ISTEA mandated the development of an automated highway system to serve as the prototype for future fully automated IVHS systems. The U.S. DOT carried out this ambitious program by sponsoring a competitive process to form the National Automated Highway System Consortium (NAHSC) in late 1994. NAHSC was comprised of nine core organizations, both public and private—General Motors, Bechtel Corporation, Caltrans, Carnegie Mellon University, Delco Electronics, Hughes Electronics, Lockheed Martin, Parsons Brinckerhoff, and the University of California-Berkeley. The consortium researched a range of options for the automated highway demonstration that could ultimately provide safer and more convenient travel. Ultimately, it was decided to combine specially equipped lanes on limited access roadways where communication, sensor, and obstacle-detection technologies were used to automatically control vehicle throttle, steering, and braking. The vehicles and the highway collaboratively coordinated vehicle movement, successfully avoiding obstacles and improving traffic flow. NAHSC's work culminated in the Demo '97, where more than 20 fully automated vehicles operated on 1-15 in San Diego, California. While the demonstration showed the potential of combining intelligent vehicles with intelligent highways, budget pressures and a change in focus to near-term safety systems led to the project's cancellation as part of subsequent legislation. This project is an important ancestor of today's focus on automated and connected vehicles.
- A key step toward making connected and automated vehicles a reality was the Federal Communications Commission (FCC) decision in 1999 to allocate 75 megahertz (MHz) of spectrum

**29** https://www.fhwa.dot.gov/tea21/sumarat.htm

**30** https://www.fhwa.dot.gov/publications/publicroads/98septoct/tea21.cfm

**Video on the '97 Automated Highway Demonstration:**

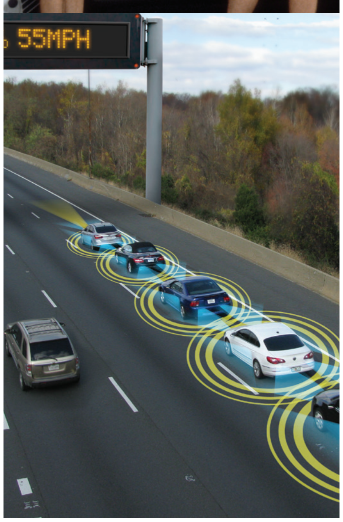
https://www.youtube.com/watch/?v=C9G6JRUmg_A

for transportation services that improve highway safety and efficiency. The 5.850 to 5.925 gigahertz (GHz) band was allocated for a variety of dedicated short-range communications (DSRC) uses as a part of the national ITS program. DSRC systems provide a wireless link to transfer information between vehicles and roadside systems. The allocation of bandwidth for DSRC catalyzed the ITS JPO's focus on connected vehicle research. DSRC is essential in many present-day research initiatives with goals of improving traveler safety; decreasing traffic congestion; and facilitating environmental benefits, such as the reduction of air pollution and conservation of fossil fuels.

- A related milestone in the movement toward connected and automated vehicles was the development of the Crash Avoidance Metrics Partnership (CAMP). Ford and General Motors formed CAMP in 1995 to accelerate the implementation of crash avoidance countermeasures to improve traffic safety. This partnership has proven invaluable in its ability to provide a way for vehicle manufacturers and various other stakeholders to collaborate on pre-competitive crash avoidance research projects of mutual interest. Much of today's intelligent vehicle research has been a direct result of this partnership.
- Another precursor to automated vehicles was the project called "No Hands Across America." Researchers from Carnegie Mellon University drove a specially outfitted 1990 Pontiac Trans Sport from Pittsburgh to Los Angeles. The car, which the researchers called the NavLab5, drove 98.2 percent of the trip as a completely autonomous vehicle.[31] The remaining percentage of time, the car needed help with tasks such as obstacle avoidance. The longest portion of the drive where the car was able to operate in a fully autonomous fashion—with no help from human operators—was approximately 70 miles.

At the current time, CAMP has Cooperative Agreements with NHTSA on vehicle-to-vehicle technology and with FHWA on V2I technology:

- Ford, General Motors, Honda, Hyundai-Kia, Mazda, Nissan, and Volkswagen/Audi are currently working with NHTSA.
- Ford, General Motors, Honda, Hyundai-Kia, Mazda, Nissan, Volkswagen/Audi, Fiat Chrysler Automobiles, Subaru, and Volvo Truck are working with FHWA.


**Top Photo:** During the 1995 "No Hands Across America" demonstration test, the NavLab5 drove 98.2 percent of the 2,849-mile trip as a completely autonomous vehicle.

Photo Source: http://www.cs.cmu.edu/~tjochem/nhaa/Journal.html

**Bottom Photo:** During the '97 Automated Highway Demonstration, more than 20 fully automated vehicles operated on the I-15 in San Diego, California.

Photo Source: U.S. DOT

31 http://www.cs.cmu.edu/afs/cs/usr/tjochem/www/nhaa/nhaa_home_page.html

# Research and Technology Developments

## FAST-TRAC

FAST-TRAC was established as a testbed for a small-scale traffic control system. FAST-TRAC integrated advanced traffic management systems (ATMS) and advanced traveler information systems. The project originated in 1992 in Oakland County, Michigan, about 15 miles from Detroit. In the late 1980s, Oakland County local governments were increasingly concerned with traffic congestion. The local governments could not afford traditional road construction to handle the demand, so instead they adopted the plan proposed by the Road Commission for Oakland County (RCOC) to use an ATMS.

In 1992, the FAST-TRAC program was invoked as a major ITS operational test. Over the years, the project has expanded and evolved. Oakland County officials were successful in securing federal earmarks under ISTEA legislation. Since the program's inception in the early 1990s, RCOC, the U.S. DOT, and the Michigan Department of Transportation have jointly funded different FAST-TRAC components, such as field tests and systems design and integration.


Signs on the roadway assist motorists in making safe lane changes prior to approaching toll collection kiosks.

Photo Source: https://thetollroadsblog.com/2014/07/02/ the-toll-roads-update-all-electronic-toll-collection/

## TravTek

TravTek was an in-vehicle traveler information system and navigation device that was developed specifically for the TravTek IVHS operational field trial, conducted from 1992 to 1993 in Orlando, Florida. The field trial was a joint project with both public and private sector entities contributing, including the American Automobile Association (AAA), FHWA, the Florida Highway Department, the City of Orlando, and General Motors. The primary objective was to obtain field data on driver acceptance and use of an in-vehicle navigation and information system.

General Motors equipped 100 Oldsmobile Toronados with the system—including a 6-inch, touch-sensitive dashboard screen—to provide navigation (based on dead reckoning and map matching with a GPS), route selection and guidance, real-time traffic information, local "yellow pages" and tourist information, and cellular phone service. Data communications between the equipped vehicles and the TMC were conducted through a specialized mobile radio. AAA selected the test subjects including rental users through Avis, and operated a TravTek Information and Services Center that was accessible via cellular telephone. The City of Orlando, in conjunction with FHWA and the Florida Department of Transportation, operated a TMC that consolidated traffic data from various sources, including probe data consisting of road segment travel times received from the equipped vehicles themselves.[32]

**TravTek Navigation System of the Future (circa 1992):**

https://www.youtube.com/watch?v=AGrxur7dMh8

## Pathfinder

The Pathfinder In-Vehicle Information System project was conducted in 1990 along the Santa Monica Freeway Corridor (I-10) in Southern California. The freeway is one of the most traveled roadways in the country. The Pathfinder project aimed to assess communications technology for route guidance and in-car traffic navigation in response to incidents and traffic congestion. Like TravTek, Pathfinder evaluated strategies for providing route guidance and in-vehicle navigation to drivers. It also demonstrated that equipped vehicles could act as roving "traffic probes," and send travel time information back to a traffic information center.

32 https://www.fhwa.dot.gov/publications/research/operations/its/jpo99038/fotatis.pdf

## Guidestar

In 1992, the Guidestar program was established between the Minnesota Department of Transportation and the University of Minnesota Center for Transportation Studies to research and deploy IVHS technologies initially in the Twin Cities and ultimately statewide. An early activity was the Genesis project, which was supported by FHWA as one of the original projects under the IVHS operational test program. Conducted in the Twin Cities area, this test used wireless personal communications devices to send drivers alphanumeric text travel information. A total of 492 participants were recruited to become Genesis users. These users provided the primary data input for the system effectiveness test, the user perception test, and the human factors evaluation.[33]

## Advantage I-75

Advantage I-75 is a partnership of public and private interests along the Interstate 75 (I-75) corridor. The goal of the partnership is to reduce congestion, increase efficiency, and enhance the safety of motorists and other users of I-75, including its connections in Canada, using ITS. I-75 passes through six different states—Florida, Georgia, Tennessee, Kentucky, Ohio, and Michigan. Project partners include FHWA, the six I-75 states, the province of Ontario, the Canadian Ministry of Transport, U.S. and Canadian trucking associations, and various trucking companies. The Advantage I-75 partnership can be traced back to a conference held in June 1990, in Lexington, Kentucky, to discuss the feasibility of conducting an ITS project for CVO on I-75. Conference participants endorsed the concept and formed a policy committee to guide development of this ITS project.

Since that time, the Advantage I-75 partnership has worked to identify areas where ITS technologies can be applied quickly to achieve immediate benefits. The Advantage I-75 program aims to incorporate existing technologies into an ITS operational setting to help the nation's highway system adapt to increasing demands. The Advantage I-75 Mainline Automated Clearance System operational test permits transponder-equipped trucks to travel any segment of the I-75 and Highway 401 corridor at mainline speeds, while being cleared to bypass the weigh stations along the corridor.

## INFORM

The INFORM (INformation FOR Motorists) project in Long Island, New York, demonstrated the impact of changeable message signs by presenting traffic flow and alternate routing information to drivers. The INFORM advanced traffic information system covered Long Island's 35-mile central corridor, comprising the island's major east/west highways and their busiest north/south connecting routes. The Long Island Traffic Information Center, operated by the New York State Department of Transportation, was at the center of this project. The prime source of information came from some 2,400 electronic sensors embedded in each roadway lane at half-mile intervals. When a vehicle moved over a sensor, it sent an impulse to the traffic information center where three INFORM computers continuously measured and analyzed changing traffic conditions. Traffic information coordinators could immediately spot delays, using data from computer monitors to determine the volume and speed of

**33** http://www.dot.state.mn.us/guidestar/1996_2000/genesis/genexecsum.pdf traffic on different sectors of the highways. The coordinators would then transmit appropriate motorist advisories to any of the 74 traffic message signs located at key points throughout the corridor. The traffic information coordinators would also notify the appropriate police and emergency organizations of traffic incidents to facilitate a quick response and resolution to problems.[34]

## Smart Bus

The Denver Smart Bus Project formed through a partnership between FTA and the Denver Regional Transportation District. The project demonstrated the use of GPS technologies to improve the management of a transit fleet and ensure on-time service and quick response to incidents.

## Dedicated Short-Range Communications

DSRC is a two-way wireless communications capability that permits very high data transmission critical in communications-based active safety applications. DSRC technologies were developed specifically for vehicular communications and have been closely associated with the connected vehicle initiative and its predecessors. In 1997, ITS America petitioned the FCC to allocate 75 MHz of spectrum in the 5.9-GHz band. In 1999, as mentioned earlier, the FCC allocated the spectrum for DSRC use. In 2004, the FCC published a Report and Order that established standard licensing and service rules for DSRC in the ITS Radio Service in the 5.850 to 5.925-GHz band (5.9-GHz band), to be used for the purpose of protecting the safety of the traveling public. Connected vehicle applications using DSRC have the potential to significantly reduce many of the most deadly types of crashes through real-time advisories alerting drivers to imminent hazards—such as veering close to the edge of the road, vehicles suddenly stopped ahead, collision paths during merging, the presence of nearby communications devices and vehicles, sharp curves, or slippery patches of roadway ahead.[35]

## Electronic Toll Collection

An electronic toll collection (ETC) system electronically debits registered car owners' accounts without requiring them to stop. This saves drivers time and decreases congestion near toll plazas. While manual toll collection lanes handle about 350 vehicles per hour and automatic coin machines can handle approximately 500 vehicles per hour, an ETC lane can handle up to 1,800 vehicles per hour in an all-electronic tolling configuration.[36]

Under Moving Ahead for Progress in the 21st Century Act (MAP-21), all ETC facilities in the United States must become interoperable by October 1, 2016.

In the 1960s and 1970s, free-flow tolling was tested by mounting transponders underneath vehicles and installing readers just under the surface of the highway.[37] In 1986, ETC was introduced in Europe. The United States followed suit shortly after. In 1991, the Oklahoma Turnpike Authority's Pikepass became the first ETC system in the United States. Since this time, ETC has become widespread across the United States.

**34** http://assembly.state.ny.us/comm/CritTran/20030401/

**35** http://www.its.dot.gov/factsheets/pdf/JPO-034_DSRC.pdf

**36** Persad, Khali and Walton, C. Michael. *Toll Collection Technology and Best Practices*. Austin: Center for Transportation Research, 2007. Project 0-5217.

**37** http://fee.org/freeman/roads-in-a-market-economy/


ETC systems save drivers time, reduce pollution, and cost less to operate and maintain than manual and coin tollbooths.

Photo Source: https://en.wikipedia.org/wiki/E-ZPass

ETC systems can provide cost savings of over $40,000 per lane for equipment costs and $40,000 per lane in annual operating and maintenance costs compared with automatic coin machines, and $135,000 per lane in annual operating and maintenance costs compared with manual tollbooths.[38] ETC lanes can also help to decrease emissions.

## E-ZPass

In 1991, the E-ZPass Interagency Group (IAG) was created to develop an interoperable tolling system that would work for seven independent toll agencies throughout New York, New Jersey, and Pennsylvania. E-ZPass was first deployed in August of 1993 at the New York State Thruway.[39]

Currently, there are 27 toll agencies spread across 16 states that make up the IAG.[40] All member agencies use the same technology. This allows travelers to use the same E-ZPass transponder throughout the IAG network. Various independent systems were integrated into the E-ZPass system, including Illinois' I-Pass and North Carolina's NC Quick Pass. Although E-ZPass has greatly expanded over the years, E-ZPass transponders are not compatible with many other ETC toll roads.

> **E-ZPass illustrates the degree of interagency cooperation necessary for interoperability…The IAG faced numerous institutional and organizational issues during the development of the E-ZPass specification. These included separate procurement procedures and requirements of the participating agencies, differences in agency missions, the pace of technological change, and parallel standard-setting efforts at the national level. In the large-scale procurement of cutting-edge technology, the IAG's regionally cooperative effort is unprecedented and provides valuable insights into the conflicts that occur and how they can be resolved.**

– Gifford, J. L., L. Yermack, and C. Owens[41]

**38** Cost-Effectiveness Analysis of AVI/ETTM for Florida's Turnpike System, Center for Urban Transportation Research, University of South Florida-Tampa, 1992.

**39** http://e-zpassiag.com/about-us

**40** http://www.e-zpassiag.com/

**41** "E-ZPass: A Case Study of Institutional and Organizational Issues in Technology Standards Development." *Transportation Research Record*, no. 1537 (November 1996): 10–14.

Photo Credit: U.S. DOT

CHAPTER 4

# THE 2000s

## The Socio-economic Environment

The first decade of the 21st century saw significant growth in communication technologies. In 2000, the number of cellular subscribers in the United States per 1,000 people was 388. By 2010, the number had shot up to 946.[42]

The number and speed of Wi-Fi networks also grew immensely during this time. Although Wi-Fi existed prior to the new millennium, the different wireless technologies were incompatible, limiting benefits. In 2000, after the development of an industry-recognized technical standard, the first generation of Wi-Fi products had a maximum data range of 11 megabits per second (Mbit/s) and operated in the 2.4 GHz band. By 2009, a new standard was brought to market, having a maximum connect rate of 600 Mbit/s and able to use both 2.4 GHz and 5 GHz bands.[43]

Cloud technology also became more prevalent during this decade. The term "the cloud" first popped up in technology circles in the mid-1990s to describe a third-party system that houses digital information on remote servers. However, during the 2000s, cloud computing became more streamlined, widespread, and affordable, allowing for significantly larger data sets to be collected and analyses to be performed.

Technological innovations that occurred during this decade have propelled ITS forward, by automating and connecting technologies and increasing opportunities for travelers to gather transportation information through social networking and smartphone applications. The need to provide and manage private sector data became increasingly important as end user expectations rose and transportation infrastructure operators and the traveling public required more accurate and timely road condition and performance data. Historically, the public sector primarily

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**42** Peterson, Michael. *Mapping in the Cloud*. https://books.google.com/books?id=mNcfAwAAQBAJ&printsec=frontcover&dq=isbn:1462510418&hl=en&sa=X&ved=0ahUKEwjp68GRlO7 MAhUEGx4KHcsmCEAQ6AEIHDAA#v=onepage&q&f=false

**43** Gratton, Dean A. *The Handbook of Personal Area Networking Technologies and Protocols*. eBook. Google Books. https://books.google.com/books?id=1aE0AAAAQBAJ&pg=PA249&lpg=PA249&dq=first+generation+of+Wi-Fi+2000+11Mbit/s&source=bl&ots=aQalKI2Xib&sig=Yv80ncxFSJtrXzoxPWORStS3s_A&hl=en&sa=X&ved=0CB0Q6AEwAGoVChMI472izLTZyAIVx3s-Ch07SgvQ#v=onepage&q=first%20generation%20of%20Wi-Fi%202000%2011Mbit%2Fs&f=false

invested in infrastructure such as vehicle sensors and cameras, and would distribute free information to end users, including agencies and private data providers. Private sector companies recognized the business opportunity in providing not only more accurate and timely data but also more data—people would pay for information. For example, NAVTEQ (registered TM), was able to make a profitable business model by providing customers with geographic information system data and base electronic navigable maps. The growth of smartphone technology and the impact on real-time information access has created further opportunities to monetize transportation-related information. Smartphone platforms currently support many traffic applications, including INRIX Traffic. Similarly, the end user is empowered more than ever before to collect and share information.

The U.S. DOT's Research and Innovative Technology Administration (RITA) was created in 2005 to advance transportation science, technology, and analysis. In a report titled, *Research Activities of the Department of Transportation: A Report to Congress*, Transportation Secretary Mineta promoted his vision for RITA as an "administration that combines research-driven innovation and entrepreneurship to ensure a safe and robust transportation network." In 2014, the U.S. Congress transferred all RITA programs into the Office of the Secretary of Transportation (OST) to provide opportunities for increased research collaboration and coordination. The ITS JPO was included under RITA and is now organized programmatically under the Office of the Assistant Secretary for Research and Technology. In 2015, the U.S. Congress directed that the ITS JPO be administered by the Federal Highway Administration, in consultation with relevant modal administrations.

## Policy and Programs

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law by President George W. Bush in August 2005. SAFETEA-LU was a transportation funding and authorization bill that focused on federal surface transportation spending. The measure designated $286.4 billion to improve and maintain the surface transportation infrastructure in the United States. In general, the bill continued the ITS research program as indicated in TEA-21, but modified the language to make technical changes and reflect new programmatic priorities. Research priorities included enhancing mobility and productivity; utilizing interdisciplinary approaches; addressing traffic management, incident management, toll collection, and traveler information; enhancing intermodal use of ITS for diverse groups; and facilitating the integration of intelligent infrastructure, vehicle, and control technologies. The bill required the development of a National ITS Program Plan, an ITS Advisory Committee, National Architecture and Standards, Rural Interstate Corridor Communications Study, Road Weather Research and Development Program, and Multistate Corridor Operations and Management. Congress renewed its funding formulas 10 times after its expiration date, until eventually replacing the bill with the Moving Ahead for Progress in the 21st Century Act (MAP-21) in 2012. SAFETEA-LU affirmed the growing return on ITS investment and contained provisions to embed ITS into the mainstream of transportation planning and deployment processes, as well as to increase general awareness of improved operations brought about by the adoption of ITS applications.


The ITS JPO launched the MSAA initiative to provide a coordinated effort and apply technological solutions to the barriers to accessibility and mobility for the transportation disadvantaged.

Photo Source: U.S. DOT

**“The smartphone was important to the history of ITS because it gave the broad public a means of envisioning technologies such as connected vehicles or automated vehicles becoming a reality within their lifetime.**

— Interviewee

After the allocation of 75 MHz of spectrum for use by ITS in 1999, the U.S. DOT's ITS Program and its partners became more acutely interested in the tremendous potential of vehicle-to-vehicle (V2V) and V2I technologies to address highway safety problems and other transportation challenges. The U.S. DOT launched the Vehicle-Infrastructure-Integration (VII) Program in 2003. The VII vision was to use wireless communication with and between vehicles to achieve dramatic safety and mobility improvements. In 2005, the U.S. DOT initiated a program to develop and test a 5.9 GHz-based VII proof of concept (POC). This effort was a continuation of the automated vehicle control systems (AVCS) as envisioned in Mobility 2000. These communication capabilities are used to exchange safety messages and improve traffic flow. The ITS JPO sponsored VII as a public-private partnership between the U.S. DOT, state and local governments, the automobile manufacturers, and other private entities, such as technology and telecommunications providers and consultants.

U.S. DOT conducted a POC test to investigate the technical feasibility of V2V and V2I applications. The POC was conducted in 2008 and 2009 in testbeds located in Michigan and California. The first DSRC multi-channel radios were built for the test vehicles, and the first instrumented roadside equipment was installed at the testbed sites. The POC testing determined that the concept was technically sound and feasible.

The VII Program progressed into commercial testing around the same timeframe as the commercial explosion in mobile communication devices, including smartphones and 3G networks. The ITS JPO realized it needed to expand its scope to explore the potential applications of the new wireless technologies.

In 2006, the U.S. DOT collaborated with CAMP to develop and test prototype V2V safety applications. The overarching goal was to determine whether this technology would work better than existing vehicle-based safety systems, like adaptive cruise control, to address imminent crash scenarios. Sound, robust data, such as that generated from CAMP's research, was required for NHTSA to make an informed decision on the future of V2V and V2I safety communications systems. In addition to drawing information from previous tests and modeling, the Connected Vehicle Safety Pilot was a major source of robust data. This empirical data was critical to supporting the 2013 NHTSA agency decision on vehicle communications for safety.

The Mobility Services for All Americans (MSAA) initiative began in 2005 as a result of the Executive Order on Human Service Transportation Coordination (#13330) issued by President George W. Bush. MSAA aims to improve transportation services and access to employment, healthcare, education, and other community activities through a coordinated effort enabled by various ITS technologies and applications.

The MSAA initiative was built on several past and current U.S. DOT-led activities, including the United We Ride Program, to increase mobility and accessibility for the transportation disadvantaged and the general public and achieve more efficient use of federal funding resources through technology integration and service coordination. The key to effective and efficient coordination under MSAA is integrating ITS technologies into a physical or virtual traffic management and control center that networks all parties together and uses ITS technologies that have demonstrated significant benefits and return on investment. These technologies include fleet scheduling, dispatching, and routing systems; integrated fare payment and management (payment, collection, and processing) systems; better traveler information and trip planning systems, particularly for customers with accessibility challenges; advanced geographic information systems; and demand-response systems to provide door-to-door service.

## Research and Technology Developments

### Driver Assistance Systems

Each year, over 6 million crashes occur on U.S. highways. They kill more than 42,000 people, injure approximately 3 million others, and cost more than $230 billion per year. Driver error is the leading cause of highway crashes. The U.S. DOT's Intelligent Vehicle Initiative (IVI) Program was established in 1998 to help reduce the number and severity of these crashes through the development and commercialization of driver assistance products that warn drivers of dangerous situations, recommend actions, and even assume partial control of the vehicles to avoid collisions. The U.S. DOT also established the Integrated Vehicle-Based Safety Systems (IVBSS) initiative to develop and test integrated safety systems on both light vehicles and commercial trucks through partnerships with private vehicle industries.[45]

> "The U.S. DOT's investment in crash prevention technologies will profoundly impact human lives.
>
> — Christine Johnson, Former ITS JPO Director

Under the IVBSS initiative, in November 2005, the U.S. DOT entered into a cooperative research agreement with a private consortium led by the University of Michigan Transportation Research Institute (UMTRI) to build and field test an IVBSS designed to prevent rear-end, lane change, and run-off-road crashes. The prototype vehicles provided forward collision warning, lane departure warning, lane change warning, and curve speed warning functions. During the first 2 years of the program, the industry team designed, built, and conducted tests to verify the prototype systems on passenger cars and heavy trucks. The prototype vehicles underwent a series of closed-course track tests aimed at ensuring that the integrated system met the performance requirements. During the second phase, the industry team built a vehicle fleet of 16 passenger cars and 10 heavy trucks for use in the field test.[46]

This initiative directly led to the collision warning and driver assistance systems that appear today on a wide range of vehicles. These features include lane departure warning, blind spot monitoring, and collision avoidance systems. Most of these systems use either cameras or sensors mounted

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**45** http://www.its.dot.gov/research_archives/ivbss/index.htm

**46** https://one.nhtsa.gov/Research/Crash-Avoidance/Vehicle%E2%80%93Based%20Safety%20Systems?_ga=1.21681 4486.1698371538.1456169305 around the car to determine whether vehicles are near the equipped car, or where the equipped car is in relation to other objects. Beginning around 2007, these features were introduced on luxury cars and have now expanded to mainstream cars. In 2014, based on the promising results of this research, NHTSA mandated back-up cameras in all vehicle built in or after May 2018.

## 511: National Traveler Information Telephone Number

On March 8, 1999, the U.S. DOT petitioned the FCC to designate a nationwide three-digit telephone number for traveler information. On July 21, 2000, the FCC designated 511 as the single traffic information telephone number to be made available to states and local jurisdictions across the country.[47] The first 511 traveler information system was launched in the Cincinnati-Northern Kentucky metropolitan area in June 2001. The first statewide 511 traveler information system was launched in the State of Nebraska in October 2001. In the first 5 years after 511 was launched, more than 50 million 511 calls were made. The unexpected invention and growth of smartphones and traveler information apps eventually inhibited the relevance and long-term popularity of 511. However, the 511 coalition was categorically successful in encouraging states to establish collaborative working relationships with an eye toward technology deployment.

## *Clarus*

*Clarus* is a U.S. DOT initiative that provides clear, relevant information on roadway conditions to all transportation managers and users. The *Clarus* initiative was established in 2004 to reduce the impact of adverse weather conditions on surface transportation users. *Clarus* developed an integrated surface transportation weather observing and data management system that was designed to enable various public agencies to more accurately assess weather and pavement conditions, as well as their impacts on maintenance and operations. Such knowledge is critical for planning, conducting, and evaluating the effectiveness of activities such as winter road maintenance, weather-responsive traffic management, traveler information dissemination, safety management, transit vehicle dispatching, and flood control. *Clarus* featured data ingest that was very low impact for the participating U.S. state and local DOTs and Canadian provinces. The U.S. DOT built metadata that was highly configurable for each participant to "screen" how data came in and what data was available through the interface. All the data were quality checked for reasonableness using sensor ranges, climate ranges, step tests, and spatial tests against nearby stations and the National Weather Service (NWS) Automated Surface Observing System to demonstrate the validity of the road weather instruments. The data were made available through multiple methods including a map with current observations, on-demand requests, and subscriptions. When the *Clarus* system retired in June 2014, there were 36 state and 5 local DOTs and 4 Canadian provinces providing observations, which represented 2,437 environmental sensor stations, 388 connected vehicles, and 54,251 individual sensors. Government agencies (federal, state, provincial, and local), academic institutions, weather service providers, television stations, and private sector firms used *Clarus*. The *Clarus* initiative has transitioned into two tracks: 1) Operational—NOAA's Meteorological Assimilation Data Ingest System; and 2) Research—FHWA's Weather Data Environment.


**Top Photo**: Roadside signs advertise the availability of 511 traveler information services.

Photo Source: https://commons.wikimedia.org/wiki/ File%3ACall_511_travel_info_sign.jpg

**Bottom Photo**: Advanced traveler and roadway condition information can improve safety and assist maintenance vehicles during adverse weather conditions.

Photo Source: U.S. DOT

**47** https://www.fhwa.dot.gov/trafficinfo/511what.htm

## DARPA Grand Challenge

The DARPA Grand Challenge was a first-of-its-kind race to stimulate the development of self-driving vehicles. Fifteen vehicles competed in the inaugural challenge, which took place outside of Barstow, California, on March 13, 2004. The long-term goal of this project was to accelerate the development of technology for autonomous vehicles that could ultimately replace men and women in hazardous military operations. Ultimately, none of the vehicles finished this course—the top-scoring vehicle traveled only 7.5 miles—and the $1 million cash prize went unclaimed.

**Photo on the Right**:
The DARPA Grand Challenge 2004 stimulated the development of self-driving vehicles.

Photo Source: http://archive.darpa.mil/grandchallenge04/Web_Photos/Sat/index.htm


One day after the first challenge ended, DARPA announced it would hold a second Grand Challenge in the fall of 2005. This time, five vehicles from out of the 195 teams that entered successfully, completed a 132-mile course in southern Nevada. Stanford University's entry finished first with a time of 6 hours and 53 minutes and won the $2 million prize.

> **"That first competition created a community of innovators, engineers, students, programmers, off-road racers, backyard mechanics, inventors, and dreamers who came together to make history by trying to solve a tough technical problem. The fresh thinking they brought was the spark that has triggered major advances in the development of autonomous robotic ground vehicle technology in the years since.**

—Lt. Col. Scott Wadle, DARPA's liaison to the U.S. Marine Corps[48]

In 2007, DARPA conducted the Urban Challenge, which featured driverless vehicles navigating an intricate city course in Victorville, California. Six out of 11 teams successfully completed the course, and the Carnegie Mellon University team won the first-place prize. DARPA has continued to conduct more competitions building on the Grand Challenge prize-based competition model,

48 http://www.darpa.mil/news-events/2014-03-13

including the 2014 Spectrum Challenge, the 2015 DARPA Robotics Challenge, and the upcoming Cyber Grand Challenge. Like the first Grand Challenge, these competitions aim to encourage innovation, commercial investment, and more affordable advanced technologies. Significantly, many of the engineers and scientists who competed in the DARPA Grand Challenges have gone on to work for famous private automated vehicle development projects.

## Next Generation 911

In 1968, the first 911 system in the United States was installed in Haleyville, Alabama. Similar systems were rapidly adopted across the nation. However, over time, it became clear that enhancements were needed to create a faster and more flexible system that allows 911 to keep up with communication technology.

**NG911 Timeline:**

http://www.911.gov/historyof911.html

In 2005, NHTSA and the National Telecommunications and Information Administration established the National 911 Program Office. By coordinating the efforts of states, technology providers, public safety officials, 911 professionals, and other groups, the program seeks to ensure a seamless, reliable, and cost-effective transition to a 911 system that takes advantage of new communications technologies to enhance public safety nationwide. The National 911 Office has released a Next Generation 911 (NG911) system architecture design and successfully used this architecture to conduct a NG911 POC demonstration. By capitalizing on recent technology advances, the U.S. DOT's ITS program has delivered a design and a transition plan for the NG911 system that, when implemented, will enable 911 calls from a variety of networked devices, and provide quicker delivery and more accurate information to responders and the public alike.

Several states have already begun the transition to NG911 infrastructure and others are preparing for this transition. NG911 enables the public to transmit text, images, video, and data to the 911 center. NG911 will establish more flexible, secure, and robust 911 center operations with increased capabilities for sharing data and resources, as well as more efficient procedures and standards to improve emergency response.

## Integrated Corridor Management

**ICM Video:**

https://www.youtube.com/watch?v=c9nqWXL5avo

**“Now traffic management decisions are based on both current and predicted traffic conditions, a capability that has so far been missing [...] I believe we are creating one of the most comprehensive and intelligent decision support systems in the industry today.**

—Alex Estrella, Senior Transportation Planner and ICM Functional Project Manager at the San Diego Association of Governments (AimSun Online), discussing the San Diego ICM system

In 2006, the U.S. DOT launched an integrated corridor management (ICM) initiative. During the second stage of this initiative, the U.S. DOT partnered with three U.S. cities—Dallas, Texas; San Diego, California; and Minneapolis, Minnesota—all of which have congested multimodal transportation corridors. To achieve effective coordination between freeways, arterials, and transit operations, this initiative has required special analysis, modeling, and simulation (AMS) to explore whether applying ICM strategies could improve performance. The ICM project's pioneering decision support system used strategies such as network traffic prediction, online microsimulation analysis, and real-time response strategy assessments to more fully inform system managers about the current and predicted corridor performance. System managers can now anticipate problems before they arise and take preventative action using ICM strategies such as coordinated ramp metering, traffic light synchronization, and transit/bus priority. This allows for optimized capacity and efficiency, reducing delays and obtaining more reliable journey times without the need for investment in additional infrastructure. AMS findings in all three corridors suggested that ICM would increase reliability while reducing travel time, delays, fuel consumption, and emissions. Benefit-to-cost ratios for ICM ranged from 10 to 1 to more than 20 to 1 over the life of the ICM system.[49] In 2010, ICM deployment demonstrations in both San Diego and Dallas were implemented. The U.S. DOT then funded 13 deployment-planning sites to help them get over the hurdle of research to implementation. This U.S. DOT effort set the stage for widespread deployment.

TMCs and system managers can anticipate problems and take preventive actions using ICM strategies.

Photo Source: Florida DOT

## Congestion Initiative

> “Congestion is not a fact of life. We need a new approach, and we need it now.
>
> —Former Secretary Norman Y. Mineta, 2006

In 2006, the U.S. DOT launched the National Strategy to Reduce Congestion on America’s Transportation Network, known as the Congestion Initiative. The Congestion Initiative serves as a blueprint for federal, state, and local officials to address needs resulting from congestion in their localities. While tolling, transit, telecommuting, and ITS have served to alleviate congestion for years in many metropolitan areas, the Congestion Initiative aimed to demonstrate the effectiveness of deploying these strategies in combination, instead of in isolation.

In the late 2000s, the ITS JPO spent approximately $100 million on this initiative. Two elements of the Congestion Initiative are the Urban Partnership Agreements (UPA) program and follow-on Congestion Reduction Demonstration (CRD).[50] The Congestion Initiative includes a six-point plan to: (1) relieve urban congestion; (2) unleash private sector investment resources; (3) promote operational and technological improvements; (4) establish a “corridors of the future” competition; (5) target major freight bottlenecks and expand freight policy outreach; and (6) accelerate major aviation capacity projects and provide a future funding framework.[51] From 2007 to 2008, the U.S. DOT awarded grants to several metropolitan areas for implementation of congestion reduction strategies under the UPA and CRD programs—Atlanta, Georgia; Los Angeles, California; Miami, Florida; Minneapolis/St. Paul, Minnesota; San Francisco, California; and Seattle, Washington.

**49** http://www.its.dot.gov/factsheets/icm_factsheet.htm

**50** http://www.its.dot.gov/research_archives/congestion/index.htm

**51** http://www.ops.fhwa.dot.gov/speeches/i95coalitionmtg06/index.htm

CHAPTER 5

Photo Source: U.S. DOT

# THE 2010s

## The Socio-economic Environment

A variety of forces has shaped the present state of ITS technology. The economic downturn in the 2000s focused increased attention on making the most efficient use of the highway system and vehicle fleet. At the same time, communications and information technology, systems, and applications have evolved at a rapid rate. These factors ultimately led to innovative research initiatives and an explosion of new transportation apps, often combining the use of vehicles as probes with enhanced geographic location and mapping systems in the form of user-friendly mobile and in-vehicle user interfaces. Increasingly, ITS applications are considered in two contexts—for automated purposes and/or for connected vehicle purposes.

Automated vehicles are those in which at least some aspect of a safety-critical control function (e.g., steering, throttle, or braking) occurs without direct driver input. Automated vehicles may be autonomous (i.e., use only vehicle sensors) or may be connected.

Connected vehicles use wireless technology to connect vehicle information and location to other vehicles (V2V); to infrastructure (V2I); or to other modes, such as internet clouds, pedestrians, and bicyclists (V2X). The wireless technology

**Statistics from the *2010-2011 ITS America Annual Report*:**

- 70% of the population is covered by 511 systems (38 states).
- Thousands of miles of highway and arterial roads are now managed and under surveillance by TMCs.
- New model vehicles now include a wide array of safety technology not previously available (e.g., lane departure warnings, collision warning and avoidance systems, and adaptive cruise control).
- The private sector ITS market has grown: $48 billion in end-use sales; 180,000 in end-use jobs.[52]

**52** http://www.dot.ca.gov/trafficops/tm/docs/ITSA-AR-1011.pdf

**Photo on the Right**: Automated vehicles contain in-vehicle sensors, cameras, and mapping technologies to operate safely without driver input.

Photo Source: U.S. DOT


typically used for connected vehicles is DSRC, but some functions may use cellular or other types of communication.

The U.S. DOT has prioritized connectivity as an important input to realizing the full potential benefits and broad-scale implementation of automated vehicles.[53] In automated vehicles, in-vehicle sensors, cameras, and mapping allow for many safety features to function without direct driver input or interference. NHTSA has defined five levels of automation that range from no automation to full, self-driving automation. Automated vehicles on this spectrum are beginning to enter the vehicle fleet.

Autonomous vehicle development focuses primarily on potential safety benefits. Connected vehicles offer additional functions related to roadside devices and fleet-level information. Connected vehicles bring additional mobility and environmental benefits that cannot be achieved through automation alone. The ITS JPO shares the goal of advancing automation with many automotive and technology industry partners. Google, Mercedes-Benz, Tesla, and Volvo are all testing driverless vehicles across the world, and the top auto parts suppliers are researching and developing different technologies to meet the large demand for specialized systems that a self-driving car would need.

In addition to these technologies, commercial applications based on geolocation and cell phones, such as Waze and Uber, are influencing the ITS market and are part of a larger trend of shared mobility. Shared mobility—the shared use of a car, bicycle, or other low-speed mode of transportation—is one aspect of the sharing economy and enables users to obtain short-term access to transportation modes as needed, rather than requiring ownership.

**53** http://www.its.dot.gov/research_areas/automation.htm

## Policy and Programs

President Obama signed MAP-21 into law on July 6, 2012. MAP-21 funded surface transportation programs at over $105 billion for fiscal years 2013 and 2014 and created a performance-based surface transportation program that builds on many of the highway, transit, bike, and pedestrian programs and policies established in 1991 under ISTEA. MAP-21 continued support for the ITS program by restoring the ITS research budget to $100 million per year and establishing a Technology and Innovation Deployment Program for $62.5 million per year. MAP-21 changed the focus of ITS activities by directing the Secretary of Transportation to encourage deployment of ITS technologies that will improve the performance of the national highway system.

**Statistics from *Deployment of ITS: A Summary of the 2010 National Survey Results*[54]:**

- 98% of toll collection lanes offered ETC.
- 66% of fixed-route buses were equipped with AVL.
- 88% of demand-responsive vehicles were equipped with computer-aided dispatch (CAD).
- 3% of bus stops display dynamic traveler information.
- 35% of fixed-route buses are equipped with electronic real-time monitoring system components.
- 8% of arterial miles are covered by surveillance cameras.
- 50% of freeway centerline miles were covered by closed-circuit television.

In August 2014, NHTSA released an advance notice of proposed rulemaking (ANPRM) and a supporting comprehensive research report on V2V communication technology. The report included analysis of the Department's research findings in several key areas including technical feasibility, privacy, and security, as well as preliminary estimates on costs and safety benefits. The estimates show that two safety applications—Left Turn Assist and Intersection Movement Assist—could prevent up to 592,000 crashes and save 1,083 lives per year.[55]

> “Safety is our top priority, and V2V technology represents the next great advance in saving lives. This technology could move us from helping people survive crashes to helping them avoid crashes altogether—saving lives, saving money, and even saving fuel thanks to the widespread benefits it offers.

—U.S. Transportation Secretary Anthony Foxx[56]

**54** https://www.hsdl.org/?view&did=713134

**55** https://www.nhtsa.gov/press-releases/us-department-transportation-issues-advance-notice-proposed-rulemaking-begin

**56** https://www.transportation.gov/briefing-room/us-department-transportation-issues-advance-notice-proposed-rulemaking-begin

V2V technology can be combined with existing vehicle safety features to make crash avoidance safety systems more effective. It also has the potential to serve as a building block for a driverless vehicle. Although the primary goal is safety, vehicles equipped with V2V technology also have many environmental and mobility benefits. V2V technology can lessen transportation's impact on the environment by reducing fuel use and emissions and improve mobility by reducing delays and congestion, enhancing traffic flow, and making it easier for people to plan travel.

## Research and Technology Developments

### Connected Vehicle Safety Pilot

The Connected Vehicle Safety Pilot Model Deployment occurred from 2012 to 2013 in Ann Arbor, Michigan. It was the largest real-world test of connected vehicle technology to date, with over 2,700 participating vehicles using wireless safety technology to help everyday drivers avoid crashes as they traveled along their normal routes. Safety applications warned drivers with alerts such as braking vehicles ahead, vehicles in their blind spots, or impending red light violations.

After analyzing data from the pilot program, NHTSA estimated that V2V technology could prevent more than half a million accidents and save more than 1,000 lives each year if implemented across the United States. This success prompted further actions and decisions within the U.S. DOT. Then, in August 2014, NHTSA released an ANPRM and a supporting comprehensive research report on V2V communications technology. As noted previously, the report includes analysis of the Department's research findings in several key areas including technical feasibility, privacy, and security, as well as preliminary estimates on costs and safety benefits, while the ANPRM seeks public input on these findings to support the Department's regulatory work to eventually require V2V devices in new light vehicles.

### Connected Vehicle Pilot Deployment Sites

A major success within the world of connected vehicles occurred in September 2015 when the U.S. DOT announced the selection of three connected vehicle deployment sites as participants in the Connected Vehicle Pilot Deployment program. The three sites include using connected vehicle technologies to improve safe and efficient truck movement along I-80 in southern Wyoming, exploiting V2V and intersection communications to improve vehicle flow and pedestrian safety in high-priority corridors in New York City, and deploying multiple safety and mobility applications on and in proximity to reversible freeway lanes in Tampa, Florida. Since September, the connected vehicle pilots have been smoothly moving forward, and we should see deployment plans for these pilots by next summer.

The U.S. DOT's goals for the Connected Vehicle Pilot Deployment program are straightforward—accelerate deployment, measure impact, and uncover the technical and non-technical barriers to deployment in a hands-on way. The Connected Vehicle Safety Pilot was primarily a V2V communication demonstration. The regional connected vehicle pilots will feature more V2I applications that go beyond safety to address additional promises of connected vehicles such as improving mobility, transit connections, pedestrian safety, fuel savings, speed harmonization, and much more. This pilot deployment program will take the findings from the Safety Pilot to the next level.

The U.S. DOT's pilot deployments encourage partnerships between multiple stakeholders (e.g., private companies, states, transit agencies, commercial vehicle operators, and freight shippers) to deploy applications using data from multiple sources (e.g., vehicles, mobile devices, and infrastructure) across all elements of the surface transportation system (i.e., transit, freeway, arterial, parking facilities, and tollways) to support improved system performance and enhanced performance-based management. The pilot deployments are also expected to support an impact assessment and evaluation effort that will inform a broader cost-benefit assessment of connected vehicle concepts and technologies.

## Washington State Department of Transportation Active Traffic Management

In August of 2010, Washington State Department of Transportation (WSDOT) launched the active traffic and demand management (ATDM) system to reduce collisions associated with congestion and blocked lanes. The system uses overhead lane signs to provide advanced notice of traffic conditions, variable speed limit signs to direct drivers to reduce speeds, symbols to indicate a lane is blocked, and overhead message signs to warn drivers of traffic ahead. WSDOT is one of the first state transportation agencies to use this type of ATDM system in the United States. These advanced notice technologies decrease dangerous, panicked braking and avoidance maneuvers, which are primary factors that contribute to collisions.

## Environmental Research

The U.S. DOT's Applications for the Environment: Real Time Information Synthesis (AERIS) research program develops advanced vehicle applications that reduce transportation's impact on the environment. More specifically, the AERIS research program generates and acquires environmentally-relevant real-time transportation data to support and facilitate "green" transportation choices. The AERIS research program employs a multimodal approach and encourages the development of technologies and applications that reduce fuel use and resulting emissions.

One application that was successfully developed by the AERIS research program is GlidePath. The GlidePath application uses cooperative adaptive cruise control and wireless communications with traffic signals to control a vehicle's approaching and departing speed in an eco-friendly manner. The FHWA's Saxton Transportation Operations Laboratory recently implemented and successfully demonstrated the GlidePath prototype application. Initial testing results indicate that the automated GlidePath prototype application provides up to a 22-percent fuel improvement over an uninformed driver.

## Private Companies Investing in Automation

Private companies investing in automation technologies vary greatly in both their background and their approach to automation. In the race to automation, traditional automobile companies are joined by tech giants like Google and Apple and less traditional auto companies like Tesla Motors. Many of the automobile companies investing in this space have faith in an incremental solution. They have researched and implemented software and mechanics that allow for level 2 and level 3 automation (see sidebar on the following page for a description of the NHTSA levels of automation). At these levels of automation, the driver must remain alert for instances where they must take over (including situations like roadwork, lane alterations, and emergency vehicles). This incremental approach allows for a new relationship between the driver and car, one that is collaborative with shared responsibilities, rather than continuous control.

Google's Self-Driving Car project started in 2009. Originally, they outfitted existing vehicles, including the Toyota Prius and the Lexus RX450h. However, Google now has a new self-driving vehicle

Autonomous vehicles will allow drivers to become passengers and engage in other activities while commuting, such as reading or catching up on work assignments.

Photo Source: http://i.kinja-img.com/ gawker-media/image/upload/t_ original/jasqyosijhfrshkbz2vl.png

prototype that they designed from the ground up, exploring options such as removing the steering wheel and pedals. They are currently testing and refining their technology in different cities around the United States and their cars have self-driven over one million miles.[57] Google's self-driving car is one of the most widely known initiatives in the automated vehicle space and has a dramatically different goal than the incremental approach discussed above. Although the current self-driving model is an example of level 3 automation, it also has a removable steering wheel and is anticipated to reach level 4 automation. Google has focused on one of the more difficult realms in the automation world—city driving. Google relies on intricate and complex maps that take into account every eventuality on a city road, from a cyclist passing to a parked car opening its door into a traffic lane.

There is an important distinction between Google's drastic self-driving approach and the more incremental automated vehicle approach. Volvo, BMW, Toyota, General Motors, and other auto companies are investing in automated cars that will look like the vehicles we drive today, taking control of the vehicle from the driver under certain circumstances. Both the automated car and the self-driving car implement the same system of sensors, radar, and GPS mapping, but self-driving cars go a step further. The steering wheel will disappear completely, and the vehicle will be solely responsible for driving.

**In 2013, NHTSA adopted the following levels of vehicle automation:**

- **No-Automation (Level 0)**: The driver is in complete and sole control of the primary vehicle controls (brake, steering, throttle, and motive power) at all times.
- **Function-specific Automation (Level 1)**: Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
- **Combined Function Automation (Level 2)**: This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
- **Limited Self-Driving Automation (Level 3)**: Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.
- **Full Self-Driving Automation (Level 4)**: The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but will not be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

57 http://www.google.com/selfdrivingcar/

CHAPTER 6

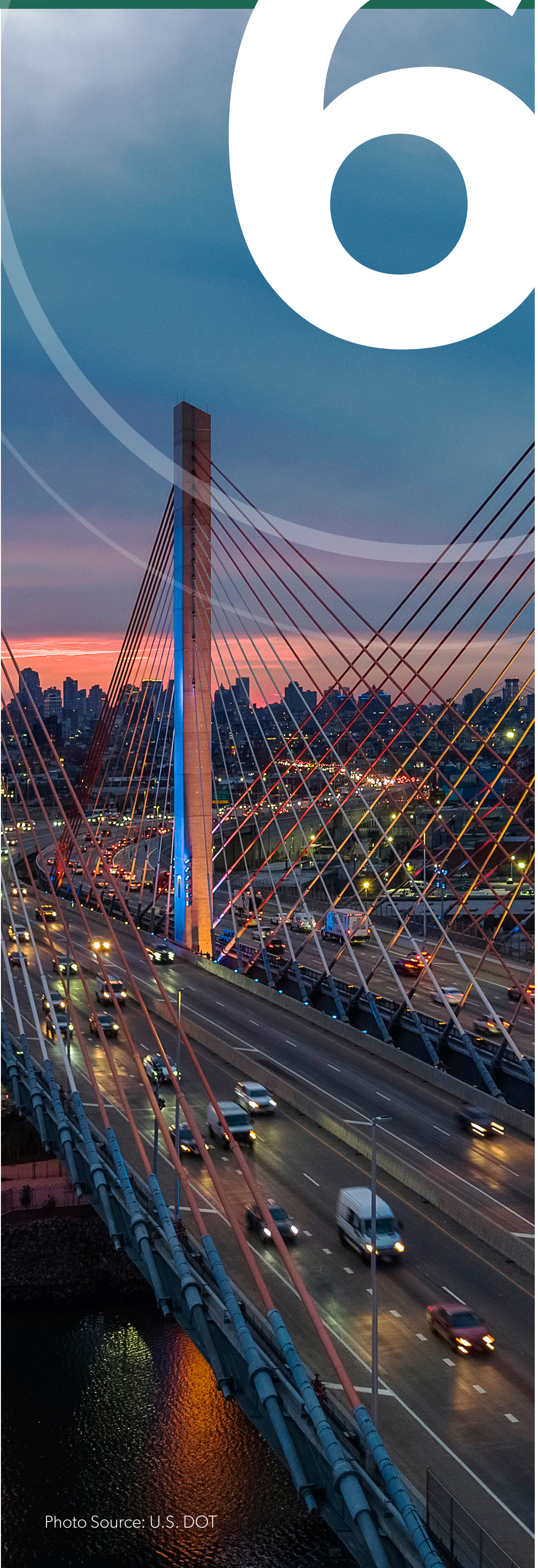

Photo Source: U.S. DOT

# 2015-2020

## The Socio-economic Environment

ITS are woven into the fabric of our nation's transportation network—in our movements on our streets, on our highways, through our communities, and throughout our daily lives. We interact with ITS technologies on a day-to-day basis without even realizing it—when we see signs telling us of road closures or work zones ahead, when we move through electronic toll booths, when we access public transit information and alerts, and more recently, when we schedule and pay for shared services such as ride and bike shares. ITS helps us navigate through our transportation system safely and smoothly.

As we look back over the past 5 years in ITS, we see that these advances in our transportation system have been increasingly shaped by the digital age and society's dependence on information and communications technologies. The pervasive spread of smart phones, mobile applications, and information at the ready has transformed our perception of what an efficient transportation system is and how best to achieve it. With traffic congestion still causing Americans to spend an extra 8.8 billion hours in travel[58], regions becoming increasingly urbanized, and heavy reliance on personal vehicle use, there has been heightened focus on how big data, connectivity, mobile applications and technologies, and automation can lead to a smarter envisioning of our transportation system—to smarter cities and communities.

Manufacturers have increasingly focused on integrating smartphones with vehicles to enhance their in-vehicle experience. In addition, cars have become more computerized with driver assistance technologies that are already helping to save lives and prevent injuries. Motor vehicles now have technology that helps drivers avoid drifting into adjacent lanes or making unsafe lane changes, or that warns drivers of other vehicles behind them when they are backing up, or that brakes automatically if a vehicle ahead of them stops or slows suddenly, among other things. These and other safety technologies use a combination of hardware (sensors, cameras, and radar) and software to help vehicles identify certain safety risks so they can warn the driver to act to avoid a crash.

58 https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-report-2019.pdf

### Statistics from *Deployment of Intelligent Transportation Systems: A Summary of the 2016 National Survey Results*

- The use of traffic adaptive signaling continues to expand rapidly and is reported by 23 percent of agencies, up from only 2 percent in 2010.
- Deployment of automatic vehicle location systems on fixed route buses has expanded to 76 percent of transit agencies, up from only 54 percent in 2010.
- The use of electronic fare payment by transit agencies is now reported by 57 percent of agencies for magnetic stripe readers and 42 percent of agencies for smart card readers.
- Adoption of probe readers to monitor traffic conditions is rapidly expanding and was reported by 52 percent of freeway agencies.
- Use of dynamic message signs deployed to disseminate traveler information continues its upward trend and is now virtually universal.
- Adoption of loop detectors is essentially universal, while 78 percent of agencies report the use of video imaging detectors, up from only 58 percent in 2010.


The U.S. DOT has focused on investing in model deployments and pilots to demonstrate the technologies and their potential benefits. The Department's Connected Vehicle Pilot Deployment Program has brought more than 10,000 connected light vehicles, trucks, fleet vehicles, traffic signals, work zones, and pedestrian devices to communities across the nation.

Photo Source: U.S. DOT

In addition, trends toward urbanism and concerns about the environment, energy, and economy have increased demand for sustainable alternatives such as shared transportation. Advances in electronic and wireless technologies have made sharing assets and data easier and more efficient. Thus, innovative mobility services continue to emerge in urban centers, leveraging the latest GPS, fare integration, and detection technologies. This has led to increased sharing of transportation services and resources among users, such as micro mobility (bike sharing, scooter sharing);

automobile modes (carsharing, rides on demand, and micro transit/shared, flexible-route minibus vehicles); and commute-based modes or ridesharing (carpooling and vanpooling).[59]

Many cities and communities are motivated by a vision of ubiquitous, smart infrastructure, systems, and services where advances in networking and information technology provide a way to increase efficiency, reduce costs, and improve quality of life for their residents.

These innovations may be enabled by accelerating the entire innovation pipeline, from fundamental research and development to testbeds for transitioning research to practice, as well as capacity-building to improve existing and new infrastructure, systems, and services. Design considerations include promoting interoperability and integration across sectors and enabling improved security and privacy.

This has been the U.S. Department of Transportation's approach for years—from developing policy and guidance, investing in research and development, and exploring ways to rebuild and improve our infrastructure and capacity.

**59** https://sharedusemobilitycenter.org/what-is-shared-mobility/

The U.S. DOT is preparing for a future transportation system of advanced technologies such as automated vehicles, vehicle connectivity, accessibility and inclusive design, mobility on demand, and increased data access and exchanges.

## Policy and Programs

### Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Grants

In 2016, the Fixing America's Surface Transportation (FAST) Act established the ATCMTD program to make competitive grants for developing model deployment sites for large-scale installation and operation of innovative transportation technologies that help reduce congestion and improve the safety of our transportation systems. With the program, the U.S. DOT funds early deployments of forward-looking technologies that can serve as national models. The U.S. DOT's intent is to drive demonstration of how emerging transportation technologies, data, and their applications improve safety, efficiency, system performance, and infrastructure return on investment.

For fiscal years 2016 through 2020, the U.S. DOT awarded $256 million to more than 45 projects using advanced ITS technologies that will improve mobility and safety and support vehicle connectivity. In its fifth year, the program is funding projects that operate with connected and automated vehicle technologies, in addition to ITS technologies to reduce congestion.

**Some of the ITS technologies being studied and developed through the ATCMTD to provide transportation benefits are:**

- Traffic congestion monitoring to improve pedestrian and bicycle safety
- Automated detection devices to reduce pedestrian-vehicle and bicycle-vehicle accidents
- Autonomous shuttles and curb space for carpool and ridesharing pick-up and drop-off
- New information systems for elderly and disabled individuals
- Real-time, data-driven traffic updates and trip planning for travelers
- Mobility on demand services to help reduce travel time and fuel consumption savings

> "The program selections this year look to the future to help ensure that our nation's highway network is able to accommodate the many advanced technologies on the horizon"
>
> —Federal Highway Administrator Nicole R. Nason[60]

60 https://highways.dot.gov/newsroom/us-department-transportation-awards-496-million-advanced-transportation-and-congestion

## U.S. DOT Automated Vehicle Policy Activities

In 2017, the U.S. DOT released *Automated Driving Systems: A Vision for Safety 2.0* (AV 2.0).[61] The guidance built on previous policy and incorporated feedback received through public comments and Congressional hearings. AV 2.0 paved the way for the safe deployment of advanced driver assistance technologies by providing voluntary guidance that encouraged best practices and prioritized safety. The following year, the U.S. DOT released *Preparing for the Future of Transportation: Automated Vehicles 3.0* (AV 3.0)[62], which expanded the scope of AV 2.0 to all surface on-road transportation systems. AV 3.0 introduced guiding principles for automated vehicle innovation for all surface transportation modes and described the U.S. DOT's strategy to address existing barriers to potential safety benefits and progress.

One output of AV 3.0 was the Automated Driving System (ADS) Demonstration Grants Program, which appropriated funding for a "highly automated vehicle research and development program." In September 2019, the Department awarded $60 million to selected award recipients to fund planning, direct research, and demonstration grants for ADS and other driving automation systems and technologies.

### ADS Demonstration Grant Award Recipients:

- Texas A&M Engineering Experiment Station – "AVA: Automated Vehicles for All"
- University of Iowa – "ADS for Rural America"
- Virginia Tech Transportation Institute – "Safely Operating ADS in Challenging Dynamic Scenarios: An Optimized Automated Driving Corridor Demonstration"
- Virginia Tech Transportation Institute – "Trucking Fleet CONOPS for Managing Mixed Fleets"
- Ohio Department of Transportation – "D.A.T.A. in Ohio: Deploying Automated Technology Anywhere"
- Pennsylvania Department of Transportation – "Safe Integration of Automated Vehicles in Work Zones"
- City of Detroit, MI – "Michigan Mobility Collaborative – ADS Demonstration"
- Contra Costa Transportation Authority – "Contra Costa Transportation Authority's ADS Demonstration Program"

Building on these efforts, the U.S. Government released *Ensuring American Leadership in Automated Vehicle Technologies: Automated Vehicles 4.0* (AV 4.0) in January 2020.[63] AV 4.0 expanded the scope of AV 3.0 to 38 relevant U.S. Government components that have direct or tangential equities in safe development and integration of automated vehicle technologies. AV 4.0

61 https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf

62 https://www.transportation.gov/av/3

63 https://www.transportation.gov/av/4

aimed to ensure a consistent federal approach to automated vehicle technologies and detail federal authorities, research, and investments so that the United States can continue to lead automated vehicle technology research, development, and integration.

In early 2021, the U.S. DOT advanced its automated vehicle efforts further by releasing the *Automated Vehicles Comprehensive Plan*[64], which builds on the principles stated in AV 4.0. The plan defines three goals to achieve the Department's vision for ADS:

- **Promote Collaboration and Transparency** – Promote access to clear and reliable information to its partners and stakeholders, including the public, regarding the capabilities and limitations of ADS.
- **Modernize the Regulatory Environment** – Modernize regulations to remove unintended and unnecessary barriers to innovative vehicle designs, features, and operational models, and will develop safety focused frameworks and tools to assess the safe performance of ADS technologies.
- **Prepare the Transportation System** – Conduct, in partnership with stakeholders, the foundational research and demonstration activities needed to safely evaluate and integrate ADS, while working to improve the safety, efficiency, and accessibility of the transportation system.

The plan reflects the Department's fundamental focus on safety, transportation system efficiency, and mobility for people and goods.

## Artificial Intelligence

On February 11, 2019, an Executive Order was issued on Maintaining American Leadership in Artificial Intelligence[65] (AI) to promote sustained investment in research and development (R&D) in collaboration with industry, academia, and other non-Federal entities to generate technological breakthrough in AI. The Executive Order directs heads of agencies to consider artificial intelligence as an R&D priority with respect to federal investment, an agency's mission, and research priorities.

While AI has applicability across many sectors of our economy, the U.S. DOT's role and activities focus broadly on two ways in which AI may be applied within transportation:

1. **First, enabling the safe integration of AI into the operations of our transportation system** across all the modes, including as a foundational technology in many automated driving systems and unmanned aircraft systems. The U.S. DOT's work in this area also focuses on safe integration of AI into conventional aircraft systems as well as traffic management operations across modes.
2. **Second, adopting and deploying AI-based tools into internal operations, research, and citizen-facing services.** The U.S. DOT has focused investments in the application of AI into improving the efficiency and effectiveness of internal processes and research, including natural language processing, computer vision, and machine learning-based predictive analytics.

Automated Vehicle Transparency and Engagement for Safe Testing (AV TEST) Initiative

In June 2020, the U.S. DOT announced the Automated Vehicle Transparency and Engagement for Safe Testing (AV TEST) initiative. As developers continue to improve their automated driving systems, they validate their laboratory and track-testing with controlled testing on public roads. Now, states and companies can voluntarily submit information about automated vehicles and testing to NHTSA, as part of the AV TEST Initiative web pilot. This information is provided to the public through an interactive online tool.

Photo Source: U.S. DOT


Artificial Intelligence Integrated Transportation Management System (AIITMS) Deployment Program

In April 2019, the U.S. DOT awarded a $4.9 million ATCMTD grant to the Delaware Department of Transportation for the AIITMS Deployment Program. AIITMS uses AI and machine learning technologies to collect and analyze high-resolution data from freeways, traffic signals, and connected and autonomous vehicles. AIITMS disseminates real-time travel information and generates traffic congestion solutions, and the system's automated data collection aims to work more efficiently than human operators. The main objective of the AIITMS program is to improve transportation safety and efficiency.

Photo Source: https://deldot.gov/Programs/itms/index.shtml?dc=projects

**64** https://www.transportation.gov/av/avcp

**65** https://trumpwhitehouse.archives.gov/presidential-actions/executive-order-maintaining-american-leadership-artificial-intelligence/

# Research and Technology Developments

In 2015, the ITS JPO released the *ITS Strategic Plan 2015-2019.* The plan presented the next set of priorities, strategic themes, and program categories for ITS research, development, and adoption activities. Building on the momentum and success of prior and current research from the previous decade, the plan defined two primary strategic priorities—realizing connected vehicle implementation and advancing automation. These priorities were in line with overall U.S. DOT strategic priorities that focused on increasing safety, enhancing mobility, limiting environmental impacts, and promoting innovation and information sharing.

The *ITS Strategic Plan* included program categories to provide the necessary structure for research, development, and adoption of ITS technologies.

- *Connected Vehicles:* Primarily focused on adoption and eventual deployment of the system
- *Automation:* Focused on topics related to automated road-vehicle systems and related technologies that transfer some amount of vehicle control from the driver to the vehicle
- *Emerging Capabilities:* Focused on future generations of transportation systems
- *Enterprise Data:* Continued existing efforts in operational data capture from stationary sensors, mobile devices, and connected vehicles and expands into research activities involving the development of mechanisms for housing, sharing, analyzing, transporting, and applying those data for improved safety and mobility across all modes of travel
- *Interoperability:* Focused on how to ensure effective connectivity among devices and systems
- *Accelerating Deployment:* Advanced the work from adoption to wider-scale deployment in coordination with several other DOT agencies.

The Ann Arbor Connected Vehicle Test Environment (AACVTE) expanded the infrastructure footprint of the Safety Pilot Model Deployment from northeast Ann Arbor to the entire 27 square miles of the City of Ann Arbor—from 25 to 75 roadside units at intersections, curves, pedestrian crosswalks, and even one roundabout. The AACVTE transitioned from research mode to an operational deployment and from a government-funded project to one that is self-sustaining. The University of Michigan Transportation Research Institute and its partners operated, maintained, and upgraded this unique connected vehicle test environment from 2015 to 2018.

Photo Source: https://aacvte.umtri.umich.edu/

## Connected Vehicles

The Connected Vehicle Safety Pilot Model Deployment occurred from 2012 to 2013 in Ann Arbor, Michigan. It was the largest real-world test of connected vehicle technology, with over 2,700 participating vehicles using wireless safety technology to help everyday drivers avoid crashes as they traveled along their normal routes. Safety applications warned drivers with alerts such as braking vehicles ahead, vehicles in their blind spots, or impending red-light violations.

In addition, the ITS JPO funded Connected Vehicle Test Beds for users to conduct a variety of tests, including signal phase and timing (SPaT) communications; security system operations; and other connected vehicle applications, concepts, and equipment. Initially based in Michigan, test bed capabilities were expanded to affiliated and interoperable test beds in Virginia, Florida, California, New York, and Arizona. These sites specialized in specific testing capabilities, such as traffic and mobility, commercial vehicles, and other functions.

### Connected Vehicle Pilot Deployment Program[66]

In 2015, the ITS JPO supported the advancement of connected vehicle technology with a pilot deployment program that aimed to uncover the barriers to connected vehicle deployment and how to address them, document lessons learned, and serve as a template to assist other early deployments. The program awarded cooperative agreements collectively worth more than $45 million to three pilot sites being led by the New York City Department of Transportation (NYCDOT), the Tampa Hillsborough Expressway Authority (THEA), and the Wyoming Department of Transportation (WYDOT). Each site worked to design, build, and test deployments of integrated wireless in-vehicle, mobile device, and roadside technologies.

The sites are currently operational with system impact being monitored on key performance measures.

### Certification

In 2015, the ITS JPO competitively selected three certification service providers to support certification testing for the Connected Vehicle Pilots. The vision was to help the industry organize and run a self-sustaining certification program supporting deployment of dedicated short-range communications (DSRC)-based services.

As part of this effort, the ITS JPO hosted Connected Vehicle Technology Plugfests at sites across the country from 2016 to 2017. These events provided a venue for vendor-to-vendor connected vehicle device testing as needed to develop certification services for multi-vendor connected vehicle networks. The PlugFests centered around conformance of devices utilizing 5.9 GHz DSRC technology. Most of the testing focused on interoperability and conformance to standards for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, together known as vehicle-to-everything (V2X) communications.

### Security Credential Management System (SCMS)

With the movement toward connectivity in our nation's transportation system, ensuring the security of such a system was a prominent concern. As connected vehicle applications exchange information among vehicles, roadway infrastructure, traffic management centers, and wireless mobile devices, a security system is needed to ensure that users can trust in the validity of information received from other system users—indistinct users whom they have never met and do not know personally.

For this reason, in 2017, the ITS JPO partnered with the automotive industry and industry security experts through the Crash Avoidance Metrics Partnership (CAMP) to design and develop a proof-of-concept (POC) security system that enabled users to have confidence in one another and the system as a whole. Subsequently, the POC SCMS has been retired, and multiple commercial SCMS vendors are operating and providing certificates for real-world connected vehicle deployments. The ITS JPO has been committed to ensuring that connected vehicle technologies operate in a safe, secure, and privacy-protective manner.

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**66** https://www.its.dot.gov/pilots/

### Cybersecurity

In May 2017, Presidential Executive Order 13800 was issued holding federal agencies accountable for managing cybersecurity risks to their ecosystem and encouraging them to work with all entities to adopt the National Institute of Standards and Technology (NIST) Cybersecurity Framework. This order paved the way for the ITS JPO to advance its cybersecurity research in response to the immediate need to protect ITS from cyber-attacks. The ITS JPO partnered with the Connected Vehicle Pilot sites to adapt the NIST Cybersecurity Framework for connected vehicle environments.

### Interoperability

In June 2018, the U.S. DOT's ITS JPO successfully conducted a limited interoperability test with the Connected Vehicle Pilots at FHWA's Turner-Fairbank Highway Research Center in McLean, VA. The goal of this demonstration was to have a vehicle with an onboard unit from one of the three Connected Vehicle Pilot sites able to interact with onboard units and roadside units from each of the other sites in accordance with the key connected vehicle interfaces and standards.

Messages between vehicles were successfully transferred over multiple communications media—and most importantly, interoperability was successfully demonstrated.

## Automation

ITS JPO automation research has aimed to support the federal role in automation safety assurance, infrastructure interoperability, and policy analyses. The ITS JPO partnered with multiple agencies in researching automation, including investigating how light-duty vehicle cooperative ADS can improve the operations of freeways and surface streets, with a focus on traffic signal systems and freeway speed harmonization. The ITS JPO's research also involved the cross-section of automation and data, and how access to data is a critical enabler for the safe, efficient, and accessible integration of automated vehicles into the transportation system.

### Data and Automated Vehicles

In 2017, the ITS JPO hosted a Roundtable on Data for Automated Vehicle Safety to explore voluntary data exchanges to accelerate the safe deployment of automated vehicles. The ITS JPO validated with private and public-sector stakeholders that there is a unique federal role in convening and facilitating voluntary data exchanges to accelerate safe deployment of automated vehicles that complements and enables activities outside the federal government.

In 2018, the U.S. DOT launched Data for Automated Vehicle Integration (DAVI) as a multimodal initiative to identify, prioritize, monitor, and – where necessary – address data exchange needs for automated vehicle integration across the modes of transportation.

One of DAVI's efforts, the Work Zone Data Exchange (WZDx) project, originated in response to priorities identified in the *Summary Report on the Roundtable for Automated Vehicle Safety.* The goal of the project was to make travel on public roads safer and more efficient through ubiquitous access to data on work zone activity. Up-to-date information about dynamic conditions occurring on roads—such as construction events—can help ADS and humans navigate safely and efficiently

**WZDx Demonstration Grants:**

In January 2021, the U.S DOT awarded $2,372,254 for WZDx Demonstration Grants to fund 13 projects in 13 states. The funding opportunity is for public roadway operators to make unified work zone data feeds available for use by third parties and collaborate on the WZDx Specification development.

- **Arizona:** The County of Maricopa, along with Arizona Department of Transportation and partner agencies, will extend a pilot WZDx data feed to the entire county, including local, regional, and national highway system.
- **California:** Metropolitan Transportation Commission will update the 511 San Francisco Bay system to generate WZDx data feeds.
- **Colorado:** Colorado Department of Transportation will pilot the use of an autonomous truck mounted attenuator to provide a real-time data feed for the work zone in which the attenuator is used.
- **Georgia:** Georgia Department of Transportation will extend existing lane closure system to include new data capture and exchange capabilities to produce WZDx feeds.
- **Iowa:** Iowa Department of Transportation will demonstrate the use of smart arrow board technology to provide validated and granular information for WZDx data feeds statewide.
- **Maryland:** Maryland State Highway Administration will produce a statewide WZDx data feed and integrate it with the University of Maryland's Regional Integrated Transportation Information System platform for distribution.
- **Massachusetts:** Massachusetts Department of Transportation will extend the WZDx specification to include smart work zone data, specifically including field device information and traffic metric data.
- **Minnesota:** Minnesota Department of Transportation will generate WZDx data feeds statewide and create a mobile tool for workers to check-in to a work zone when beginning work, advancing safety, efficiency, and innovation.
- **Missouri:** St. Charles County will develop a corridor-level deployment of new WZDx-compliant data feed for cities and counties within the county.
- **Utah:** Utah Department of Transportation will demonstrate WZDx data feed deployment across six work zones in urban, rural, and freeway environments.
- **Virginia:** Virginia Department of Transportation will generate WZDx data feeds for all work zones statewide.

*(continued on next page)*

**WZDx Demonstration Grants** (continued):

- **Washington:** Washington Department of Transportation will pilot WZDx data feed deployment by automating data gathering and validation for work zones and other non-recurring events requiring temporary traffic control
- **Wisconsin:** Wisconsin Department of Transportation will extend the capacity of the Advanced Traffic Management System to produce a statewide data feed.

Inspired by the General Transit Feed Specification (GTFS), the U.S. DOT launched WZDx to jumpstart the voluntary adoption of a basic work zone data specification through collaboration with data producers and users. The U.S. DOT partnered with five state departments of transportation and six companies from private industry to help define the core data elements that should be included in the work zone specification and to determine what types of technical assistance the data producers will need to implement the specification.

The Federal Highway Administration (FHWA) and ITS JPO co-led the early stages of the WZDx project and remain actively involved along with the Bureau of Transportation Statistics, Federal Motor Carrier Safety Administration, and others in the U.S. DOT. Several data producers and data users voluntarily developed version 1.1 of the specification in collaboration with U.S. DOT and have started to set up data feeds based on it. Version 3.0 of the WZDx Specification was published in September 2020.

### CARMA

The FHWA partnered with the ITS JPO, the Federal Motor Carrier Safety Administration, the Maritime Administration, and the Volpe National Transportation Systems Center in the development of CARMA, a platform to facilitate collaboration among ADS developers and improve transportation efficiency and safety.The overarching purpose of CARMA is to transform transportation, improving efficiency and safety through automated vehicles working together with roadway infrastructure.

CARMA started out as a proof of concept software package developed to enable vehicles to communicate their longitudinal movements with each other. It marked the start of FHWA's cooperative automated vehicle fleet. It then progressed to an open-source software platform to engage with the industry on CDA to expand existing automation capabilities and reduce research and development time. The latest version was released in July 2019 and consists of CARMA Cloud (a downloadable, cloud-based, open-source service that enables communication between cloud services, vehicles, road users, and infrastructure devices) and the CARMA Platform (open-source software that enables researchers and engineers to develop and test their CDA features on properly equipped vehicles).

Designed using open-source software and available on GitHub, CARMA allows ADS technologies to operate more safely and efficiently. The tool was created to work with any vehicle, hardware, or control system, thereby simplifying software development and providing access to much-needed functionality. It also allows for a community of developers to come together to share knowledge and make progress in transportation research and development.

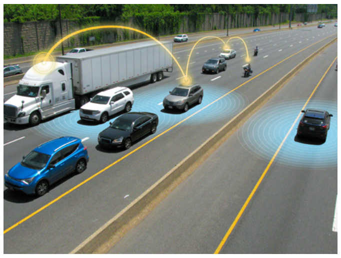
## Emerging Capabilities

### Spectrum Interference Testing

In May 2015, the ITS JPO announced a series of initiatives to speed the development of advanced technologies that could enhance highway and roadway safety. Among those initiatives was an effort to prepare to test the safety impact of wireless devices designed to share the section of the radio spectrum reserved for vehicle safety applications such as V2V and V2I communications in the 5.850 MHz to 5.925 MHz band.

In cooperation with other federal partners, including significant input from the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration, the ITS JPO developed a draft analysis plan that created a baseline to support further analysis of spectrum sharing within 12 months of receiving test devices from industry.

The ITS JPO launched DSRC-UNII-4 Sharing Testing in August 2019. In early 2020, the U.S. DOT launched a parallel test program to test Cellular Vehicle-to-Everything or long-term evolution (LTE) CV2X in safety-related, challenging transportation conditions.



In early 2017, NHTSA published a Notice of Proposed Rulemaking to mandate V2V communications for new light vehicles and standardize the message and format of V2V transmissions.[67]

Photo Source: U.S. DOT

### Mobility on Demand (MOD)

In 2015, the U.S. DOT launched the MOD program, an initiative led by the ITS JPO and the Federal Transit Administration (FTA) to enable and leverage advancements in technology and operations to create an environment where all travelers have safe mobility options. The vision was to ensure reliable, informed, and efficient travel in a multi-modal network that prioritizes individual, on-demand mobility.

In 2016, in collaboration with the ITS JPO, FTA launched the MOD Sandbox program through a Notice of Funding Availability (NOFA). The MOD Sandbox provides a platform where integrated MOD concepts and solutions, supported through key local partnerships, are demonstrated in real-world settings. Four key guiding principles of the MOD Sandbox are that it encourages system integration, innovative business models, equity of service delivery, and partnerships. Through cooperative agreements, FTA and the ITS JPO have collaborated closely with selected transit agencies and communities across the country to implement and evaluate innovative approaches and business models to integrate MOD solutions within a public transportation framework.

#### MOD Sandbox Grants

| State | Description |
|---|---|
| **AZ** | The Regional Transportation Authority of Pima County will receive funding for the Adaptive Mobility with Reliability and Efficiency project, integrating fixed route, subscription based ride-sharing and social carpooling services into an existing data platform to provide affordable, convenient and flexible service. The project augments transit by addressing first mile/ last mile issues and congestion mitigation by incorporating shared ride-on-demand services, integrated open payment systems and advanced traveler information systems. |

**67** https://www.federalregister.gov/documents/2017/01/12/2016-31059/federal-motor-vehicle-safety-standards-v2v-communications

| State | Description |
|---|---|
| **AZ** | Valley Metro Rail of Phoenix will receive funding for a smart phone mobility platform that integrates mobile ticketing and multimodal trip planning. The network will include a range of mobility providers, including ride-hailing, bike sharing, and car-sharing companies, allowing all levels of income, age and people with disabilities to have access to an integrated, connected multimodal transportation system. |
| **CA** | The City of Palo Alto will receive funding for the Bay Area Fair Value Commuting Demonstration project, which aims to reduce single-occupant vehicle driving from 75% to 50% in the Bay Area. The project includes commuter trip reduction software, a mobility aggregation multimodal trip planning app, workplace parking rebates and analytics to compare commutes. |
| **CA (& WA)** | The Los Angeles County Metropolitan Transportation Authority will receive funding for a two-region mobility on demand partnership with the car-sharing company, Lyft*, in Los Angeles and Seattle. The project will explore the viability of first/last mile solutions for trips originating and ending at select transit stops. Customers can use the Lyft* app or call a dispatcher phone number, providing equity to lower income individuals. *Partnership changed from Lyft to Via since announcement |
| **CA** | San Francisco Bay Area Rapid Transit (BART) will receive funding for an integrated carpool to transit program that will help users find carpool matches as well as match them to their transit destinations. The project will provide a seamless way to reserve and pay for in-demand parking spaces at BART stations, allow preferential parking for carpoolers while increasing transit ridership by improving access to BART stations. The software will include ways to identify drivers with wheelchair-accessible vehicles. |
| **FL** | The Pinellas Suncoast Transit Authority will receive funding for the Paratransit Mobility on Demand Demonstration, a set of partnerships with a taxi company, a paratransit service and a car-sharing company to develop a model to provide more cost-effective on-demand door-to-door paratransit service. The project will feature a central dispatch software that provides users with a selection of transportation service providers based on an estimated time of pickup, available payment types, and physical limitations. |
| **IL** | Chicago Transit Authority (CTA) will receive funding for a project that will incorporate the local bike sharing company, Divvy, a 580 station bike share service, into CTA's existing transit trip planning app so users can identify the availability of bikes or docking stations near their transit stops, and pay for bike rentals. |

| State | Description |
|---|---|
| OR | The Tri-County Metropolitan Transportation District of Oregon (TriMet) will receive funding for an Open Trip Planner Share Use Mobility project that will create a platform integrating transit and shared-use mobility options. TriMet will build on its existing trip planning app to incorporate shared use mobility options and more sophisticated functionality and interfaces, including data sharing for shared-use mobility providers. By integrating data, the project will allow users to plan trips that address first/last mile issues while traveling by transit. |
| TX | Dallas Area Rapid Transit (DART) will receive funding for a project that integrates ride-sharing services into its GoPass ticketing app to solve first and last mile issues. This project will combine traveler applications to create an integrated, multimodal application that leverages ride-sharing services. The project will improve ease of access to DART stations, particularly in non-walkable areas not well served by transit. |
| VT | The Vermont Agency of Transportation will receive funding for a statewide transit trip planner that will enable flex-route, hail-a-ride, and other non-fixed-route services to be incorporated in mobility apps. The online trip planner for both fixed and flexible transit services particularly benefits non-traditional rural transit system users, allowing universal access to transit information, including to people with disabilities. |
| WA | The Pierce County Public Transportation Benefit Area Corporation will receive funding for the Limited Access Connections project, an initiative connecting Pierce Transit local service, Sound Transit/Sounder regional service, and local ride-share companies in order to increase regional transit use. By providing first/last mile service in and between traditional zones, guaranteed rides home, and rides to park-and-ride lots, the project will extend service hours and provide access to transit for riders who have limited transit options. |

**Smart City Challenge**

In 2016, the U.S. DOT launched the Smart City Challenge, where medium-sized cities presented ideas for how to create a fully integrated, first-of-its-kind transportation network that uses data, technology, and creativity to shape how people and goods move.

By challenging American cities to use emerging transportation technologies to address their most pressing problems, the Smart City Challenge aimed to spark and spread innovation through a mixture of competition, collaboration, and experimentation. The Department committed $40 million for one city to demonstrate how advanced data and ITS technologies and applications can be used to reduce congestion, keep travelers safe, reduce fuel consumption, connect underserved communities, and support economic vitality.

As the winner of the Smart City Challenge, Columbus, Ohio, was tasked to demonstrate how advanced technologies can be integrated into other operational areas within the city, utilizing advancements in ITS, connected vehicles, automated vehicles, and electric vehicles to meet specific challenges, while integrating data from various sectors and sources to simultaneously power these technologies, and leverage the new information they provide.

The Smart City Challenge provided a roadmap for cities looking to revolutionize their transportation systems to help improve people's lives. In the first phase of the challenge, the U.S. DOT received 78 applications – one from nearly every mid-sized city in America.

While there was only one winner, the competition allowed 77 other cities to plan for a smarter future and ignited a conversation across America about how to tackle transportation challenges.

### Accessible Transportation

With nearly 20 percent of the U.S. population comprising individuals with disabilities, and other demographic trends such as the increasing number of older Americans[68], the U.S. DOT explored emerging technologies that could expand travel options and enhance mobility for all. The Accessible Transportation Technologies Research Initiative (ATTRI) was a joint U.S. DOT initiative, co-led by the ITS JPO, FHWA, and FTA with support from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR), and other federal partners. ATTRI led efforts to develop and implement transformative applications to improve mobility options for all travelers, particularly those with disabilities. The research focused on removing barriers to transportation for people with visual, hearing, cognitive, and mobility disabilities.

**ATTRI Application Development Grants Wayfinding and Navigation:**

- City College of New York – Smart Cane for Assistive Navigation (SCAN), a wayfinding solution for those with low vision integrated with a smart phone application
- AbleLink – An open wayfinding media standard and related infrastructure to create geographically-specific, cloud-based libraries of routes in metropolitan or rural areas
- Pathways Solutions – A wayfinding tool for wheelchair users and people with visual impairment that guides users along routes tailored to their preferences
- TRX Systems – A smart wayfinding and navigation system to obtain real-time location, en-route assistance, and situational awareness.

**Pre Trip Concierge and Virtualization:**

- AbleLink – A suite of assessment, self-directed learning, and trip execution technologies to support pre-trip planning for individuals with cognitive disabilities.

68 https://www.census.gov/newsroom/releases/archives/miscellaneous/cb12-134.html

**Safe Intersection Crossing:**

- Carnegie Mellon University – A tool to connect pedestrians with disabilities to the traffic signal systems infrastructure (and nearby connected vehicles and infrastructure) and create situational awareness to improve the safety of intersection crossing and increase independent mobility.

**Robotics and Automation:**

- Carnegie Mellon University – The NIDILRR awarded a grant to Carnegie Melon University for cloud-based autonomy and shared robots located in and around transportation hubs.

In 2017, the U.S. DOT awarded six application development grants, totaling $6.185 million, under ATTRI to improve mobility options for all travelers, particularly those with disabilities.[69] The U.S. DOT's ATTRI efforts aimed to harness innovative technologies to offer all Americans enhanced travel choices and accessibility at levels once only imagined.

## Enterprise Data

As connected vehicle research and deployment evolved, the ITS JPO recognized the imminence of unprecedented levels of real-time transportation data. There were concerns about how best to manage, integrate, and share that data. DOT agencies led by the ITS JPO aligned around the need for new ways to manage data efficiently and securely through the transportation system to support the next generation of ITS technologies.

The ITS DataHub, ITS CodeHub, and the Secure Data Commons were outputs of this effort. Formerly ITS Public Data Hub, ITS DataHub provides a single point of entry to discover publicly available, reusable, and open ITS research projects and data management tools. It enables free access to research datasets and associated documentation in near-real time and decreases the time from research to insight. ITS CodeHub, which replaced the Open Source Application Development Portal, is a web-based portal that provides access to and supports the collaboration, development, and use of open-source ITS-related applications. Secure Data Commons provides a secure platform for sharing and collaborating on research, tools, algorithms, and analysis involving moderate sensitivity level datasets using commercially available tools, without needing to install tools or software locally.

By providing access to data from our research, the ITS JPO enables third-party research into the effectiveness of ITS technologies, spurs preliminary development of third-party applications, and harmonizes data across similar collections.

**69** https://www.transportation.gov/briefing-room/dot7117

## Interoperability

**National ITS Reference Architecture**

In 2017, the ITS JPO released the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT), which replaced the ITS National Reference Architecture and the Connected Vehicle Reference Implementation Architecture (CVRIA). ARC-IT provides a unifying framework for planning, defining, and integrating ITS, including connected vehicle and traditional infrastructure ITS capabilities. It is a mature product that reflects the contributions of a broad cross-section of the ITS community (transportation practitioners, systems engineers, system developers, technology specialists, consultants, etc.). The architecture reference and toolsets were the first to fully incorporate wireless connectivity with mobile participants in the transportation system.

Combining the two architectures into ARC-IT streamlined the V2I communications guidelines and funding, leading to repeatable deployments. Since its initial release, ARC-IT has undergone several updates.

## Accelerating Deployment

For over 20 years, the ITS JPO has been tracking the evaluation of ITS technologies. Throughout that time, there has been steady growth in the number of studies documenting the benefits, costs, and lessons learned of ITS. The ITS Deployment Tracking Surveys (DTS) were conducted a total of ten times between 1999 and 2016. Data is collected from freeway, arterial, and transit agencies in 78 large and 30 medium-sized metropolitan areas. The DTS were designed to collect data characterizing ITS technology deployment, as well as programs and policies implemented to support ITS.

In 2019, the ITS JPO conducted the first Connected Vehicle and Automated Vehicle Survey.[70] The 2019 survey is the first in a new series of surveys that focuses only on connected vehicle and automated vehicle technologies.

The survey found that agencies plan to deploy a variety of connected vehicle applications:

- Freeway agencies prefer applications focused on improving highway safety and mobility.
- Arterial agencies want traffic signal solutions to mobility and safety issues.
- Transit agencies select vehicle-to-vehicle safety applications and solutions to improve customer service and operations.

Safety is a common factor in all three.

**ITS Professional Capacity Building (PCB)**

For over two decades, the ITS JPO has provided the transportation workforce with flexible, accessible ITS learning and support through live and on-demand training, technical assistance, and educational resources. To ensure the ITS workforce keeps pace with advancements in ITS, the ITS JPO developed new training courses and resources related to connected and automated vehicles, including the Connected Vehicle Deployer Resources that offer an equipment loan program and help desk.

**70** https://www.itskrs.its.dot.gov/deployment/2019cvav

**Statistics from the 2019 Connected Vehicle and Automated Vehicle Survey:**

- 29 percent of freeway, 23 percent of arterial, and 25 percent of transit agencies are currently deploying connected vehicle technology.
- 54 percent of freeway, 33 percent of arterial, 54 percent of transit agencies plan to deploy connected vehicle technology within the next 3 years.
- 39 percent of agencies are conducting or have conducted automated vehicle tests or deployments.
- Of those conducting automated vehicle testing, 37 percent are testing automated fixed-route shuttle vehicles, 11 percent are testing automated flexible mobility-on-demand shuttles, and 10 percent are testing automated taxi/ride-hailing services.

In 2018, the program launched the Transportation Technology Tournament in a joint effort with the National Operations Center of Excellence. The competition is designed for students to work directly with public agencies to solve real-world transportation problems utilizing ITS and transportation systems management and operations solutions. It aims to help push the future workforce to understand the communications, teamwork, planning, and interdisciplinary skills required to work in the transportation industry.

## Other Areas

**Rural ITS**

The ITS JPO has also sought to help rural, regional, and multistate stakeholders from multiple backgrounds to positively affect transportation in rural areas. The ITS JPO has worked to identify and select ITS initiatives based on the unique transportation needs and deployment challenges in rural areas; share noteworthy practices from successful implementation in rural, regional, and multistate environments; and express the value to rural communities of these ITS technology solutions. The ITS JPO's ultimate goal is to advance ITS technologies to wider-scale deployment in rural settings in coordination with other stakeholders at the federal, state, regional, and local levels.

**International Cooperation on Intelligent Transportation Systems Research and Deployment**

International cooperation in the name of progress is always something to celebrate, and the ITS JPO published a report in 2017, *European Union – United States – Japan Cooperation on Intelligent Transportation Systems Research and Deployment 2017 International Accomplishments Summary*, describing the Department's efforts in this area. Along with the European Commission and the Ministry of Land, Infrastructure, Transport and Tourism of Japan, the ITS JPO participated in formal exchanges of knowledge and joint research meant to increase global progress on ITS research and deployment.

The ITS JPO has also collaborated with Korea, Mexico, and Canada on a range of ITS and connected vehicle technologies.

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CHAPTER 7

Photo Source: U.S. DOT

# 2021-THE FUTURE

The outbreak of COVID-19 has fundamentally changed nearly every aspect of transportation in the United States. The nation's entire transportation ecosystem was severely affected, with many elements brought to a complete standstill. In 2020, the COVID-19 pandemic caused sharp reductions in passenger travel of every type. The airline, public transit, and rail industries were particularly hard hit. Stay-at-home orders, travel bans, social distancing guidelines, safety fears, and the virus itself led to drastic reductions in travel across the United States.

In January 2021, the U.S. DOT welcomed new leadership and new priorities that aligned with those of the new Biden Administration. The safety of the traveling public and America's workers are at the center of its mission, but the U.S. DOT's vision is also focused on economic recovery, racial equity, and combating climate change.

In February 2021, the Department announced it is seeking applicants for the Fiscal Year 2021 round of the Infrastructure for Rebuilding America (INFRA) discretionary grant program.[71] INFRA grants will fund transportation projects of national and regional significance that are in line with the Biden Administration's priorities including creating good-paying jobs, improving safety, applying transformative technology, and explicitly addressing climate change and racial equity.

The Department recognizes the role that infrastructure investment plays in economic development and job creation, and the added urgency of this funding at a time when the COVID-19 pandemic has put stress on state and local budgets.

It is unclear when, or even if, pre-COVID-19 travel patterns will return. Yet America's transportation network will continue to serve as the pipeline to our communities, our livelihoods, and our productivity. Whether it's enabling the delivery of groceries, essential supplies, medical equipment, or ensuring that essential staff can get to work and perform their duties, the U.S. DOT is working to ensure that our nation's transportation system rises to the challenges caused by this pandemic.

**71** https://www.transportation.gov/briefing-room/us-department-transportation-announces-fy-2021-round-infrastructure-rebuilding

The number of trips taken by Americans in 2020 was 26 percent less than in 2019. Air travel suffered a steep drop, with a 48-percent decrease in commercial flights. Transit agencies were devastated by low ridership. New York City's MTA recorded 667 million riders in 2020, down 63 percent from 1.794 billion riders in 2019. In Washington, DC, WMATA's 53 million bus and rail riders represented a 79 percent drop from 2019's 248 million riders. The freight market has been volatile since the start of the COVID-19 pandemic, with sharp increases caused by buying panic at the beginning of lockdowns. Railroad volume dropped by 20 percent, and ocean shipping fell by 25 percent. One area that is doing markedly well is last-mile deliveries, which have seen a surge of more than 10 times as of June 2020.

Photo Source: U.S. DOT

ITS technologies can do that. For example, driverless vehicles can help solve the problem of increased demand for home delivery of goods and the simultaneous need for physical distancing. Connectivity and communications for emergency vehicles can play an important role in enabling the public safety community to respond faster to incidents while ensuring their own safety. ITS approaches through artificial intelligence, assistive technologies, ride-sourcing, and wayfinding and navigation can help users to independently travel without unnecessary interaction with others, particularly people with disabilities, older adults, and other underserved communities that often face greater challenges in accessing essential services.

These technologies can not only heal the impacts of the pandemic, but also address issues of equity for minority and low-income communities by expanding mobility options, offering demand-response services, and reducing first and last mile challenges.

In addition, ITS technologies like connected vehicle technologies and applications can support a more sustainable relationship between transportation and the environment (chiefly through fuel use and associated emissions reductions).

ITS can save lives, keep our country running, and prepare for future challenges, perils, and opportunities.

## Research and Technology Developments

Although innovations in ITS promise enormous public benefits, they also introduce new challenges. These challenges range from technical to ethical, legal, and social, including cybersecurity, data sharing and analysis, privacy, public health and well-being, workforce and education needs, and cultural and socioeconomic considerations. Addressing these challenges requires new forms of cross-sector and cross-government collaboration, experimentation, knowledge sharing, and alignment.

Recognizing this, in 2020, the *ITS JPO released the ITS JPO Strategic Plan 2020-2025*. The plan includes in-depth discussion of the ITS JPO's strategic goals, related research areas, and four technology transfer programs, which together work to accelerate deployment:

- **Accelerating ITS Deployment:** The ITS JPO wants to speed up the transformation of ITS research and prototypes into market-ready technologies that are commercially viable and adopted by the transportation community. The program provides knowledge transfer and supports standards and architecture maturity, technical assistance, training, outreach, program evaluation, and other stakeholder engagements. This includes four technology transfer programs:
  - ITS Evaluation
  - ITS Professional Capacity Building
  - ITS Architecture and Standards
  - ITS Communications.

- **Automation:** Technological progress and industry investment make this an area with real development potential in the coming decade. Having published four automated vehicle guidance documents, the DOT continues pushing forward with its vision for vehicle automation. The ITS JPO's automation research is a component of the U.S. DOT's vision of supporting the safe, reliable, efficient, and cost-effective integration of automation into the broader multimodal transportation system. The ITS JPO funds cross-modal research in vehicle automation safety, infrastructure and interoperability, and policy analysis.
- **ITS4US:** The ITS JPO's ITS4US Deployment Program is working to identify ways to provide more efficient, affordable, and accessible transportation services for people with disabilities, older adults, and other underserved communities.

**ITS4US Deployment Program Awards:**

In early 2021, the Department announced the awards of over $38 million to five projects through the ITS4US Deployment Program. The projects will enable communities to showcase innovative business partnerships, technologies, and practices that promote independent mobility for all. The three-phased effort brings together public-sponsored and private-sponsored research. It also will create large-scale, replicable deployments that generate increased mobility options across multiple modes of transportation to address the challenges of planning and executing complete trips.

- **California Association of Coordinated Transportation (CALACT)**
  - Location: California, Oregon, and Washington
  - Project: *Plan, Book, and Pay for Demand-responsive Transit Agencies in CA, OR, or WA*
  - Award: $5,311,000
- **Atlanta Regional Commission (ARC)**
  - Location: Gwinnet County, Georgia
  - Project: *Safe Trips in Connected Transportation Network*
  - Award: $9,388,404
- **Heart of Iowa Regional Transit Agency (HIRTA)**
  - Location: Dallas County, Iowa
  - Project: *Health Connector for the Most Vulnerable: An Inclusive Mobility Experience from Beginning to End*
  - Award: $3,956,806

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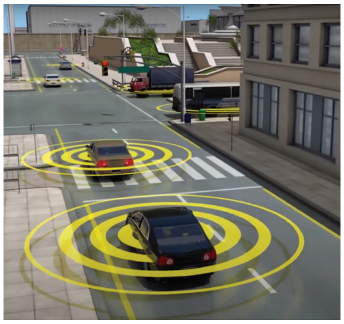
**Video on ITS: What's Available Today and the Vision for Tomorrow, July 2021**

https://www.youtube.com/ watch?v=yQE5cI7ZWec



In July 2021, the ITS JPO released a video to celebrate its 30-year anniversary. The video, *Intelligent Transportation Systems: What's Available Today and the Vision for Tomorrow*, highlighted the current and future states of ITS solutions and technologies.

Photo Source: U.S. DOT

**ITS4US Deployment Program Awards** (continued):

- **University of Washington**
  - Location: Baltimore, Maryland; Portland, Oregon; Bellevue, Washington
  - Project: *Accessible Mapping Standards and Data Collaboration Drive Accessible Multimodal Active Transportation and Mobility*
  - Award: $11,459,000
- **ICF International, Inc.**
  - Location: Buffalo, New York
  - Project: *Complete Trip Deployment in Buffalo, NY*
  - Award: $8,235,661

- **Data Access and Exchanges:** The ITS JPO is continuing its efforts to enable access to core transportation data across the ITS ecosystem, including data and source code generated through the DOT's ITS research investments, to accelerate deployment of new ITS technologies, cut the time from research to insight and policymaking, and drive secondary research results.

- **Cybersecurity for ITS:** Cyber threats to transportation systems can impact national security, public safety, and the national economy. Concerns about cybersecurity for ITS and traffic management deployments relate to both current technologies as well as legacy systems, coupled with the growing trend to integrate ITS deployments with other networks. This combination has introduced new threats that have not yet been encountered in this domain. And the cyber threat grows as the value of ITS ecosystem increases. Thus, the ITS JPO has been expanding its work in cybersecurity with increased budget and scope of activities.

In 2020, the ITS JPO released a Broad Agency Announcement to procure prototype and commercially available off-the-shelf V2X communications devices to support the U.S. DOT's 5.9 GHz "Safety Band" Spectrum Testing. The test result findings are ultimately intended to provide an objective view of the technology's capabilities, in terms of its ability to support crash-imminent safety applications involving V2V and V2I communications, as well as how LTE-C-V2X utilizes the 5.9 GHz band.

This research will provide the U.S. DOT with a significant understanding of the potential benefits and disruptions these technologies could represent to the transportation system.

Photo Source: U.S. DOT

- **Emerging and Enabling Technologies:** This area provides a mechanism for determining opportunities and risks for introducing promising innovative or disruptive technologies to transportation. The program primarily focuses on identifying, assessing, and implementing new technology such as AI in ITS as well as data/computing resources needed to promote AI for further investigation by the ITS JPO and its modal partners. Likewise, communications technologies are critical to the safe, secure, and efficient operations of ITS such as DSRC, CV2X, and 5G. The ITS JPO is working to test unproven communications technologies for transportation like CV2X and 5G and continuing research needed to inform public policy decisions on CV2X development, 5G, detect and vacate, interference and rechannelization concepts.

## The Safety Band

On November 18, 2020, the FCC approved a First Report and Order reallocating a majority of the 5.9 GHz band away from connected vehicle technologies. The Commission repurposed the lower 45 megahertz at 5.850 to 5.895 GHz for unlicensed commercial uses such as Wi-Fi.

The Safety Band is a band of wireless spectrum at 5.9 GHz reserved for transportation-related communications among the devices that support connected and automated vehicles. Interacting via the interference-free Safety Band, these high-precision devices enable communications between vehicles and traffic lights, generate real-time alerts or warnings, and adjust signals to give emergency vehicles priority in heavy traffic—dramatically improving our transportation safety and mobility. As technology advances, interoperability is central to enabling universal, nationwide, and regionwide V2X capability and benefits. Sharing the band could compromise the speed at which this information is received and put lives at risk. With over 37,000 deaths on our nation's roads every year, it is critical that efforts to free up additional spectrum do not come at the expense of lifesaving technologies.

## The Way Forward: Putting People First

In June 2021, the ITS JPO published the report *Putting People First: Smart Cities and Communities.*[72] Smart cities and communities (SC&Cs) use advanced information and communications technologies to find new ways to solve age-old problems like potholes and pollution, traffic and parking, public health and safety, and equity and public engagement. Most importantly, successful SC&Cs put people first. For communities that embrace SC&C solutions to engage people to accomplish collective goals, that future is fast arriving.

Our nation has ambitious goals for climate, equity, and economic growth that hinge on our transportation network. Local communities have led the charge to address these goals. By embracing bold policies and innovative solutions that leverage rapidly advancing technologies, communities are not only solving local problems like traffic and parking, they are creating a model for more inclusive, connected, and sustainable communities of the future.

The U.S. DOT stands ready to support local governments as we learn together from early pilots and begin moving toward integrated, sustainable systems. It begins by listening, learning, and sharing with each other what works, what doesn't, and what's next.


SC&Cs create an intelligent and integrated information network by applying sensors and wireless communications technologies to infrastructure, vehicles, wearables, and any number of physical devices.

Photo Source: U.S. DOT

**72** https://www.its.dot.gov/press/2021/smartcities_communities.htm

**Video on ITS4US Program Overview, November 2022**

https://www.youtube.com/watch?v=pztl1IRyXAc


Photo Source: U.S. DOT

# 2022 Updates

## ITS4US Deployment Program Phase 2 Awards

In June 2022, the Department awarded $27 million across four projects for Phases 2 and 3 of the ITS4US Deployment Program. The completed Phase 1 consisted of developing the deployment concept. Phase 2 of the Program includes the design, testing, and deployment of Complete Trip solutions, and Phase 3 focuses on the operation and evaluation of these solutions.

ITS4US Deployment sites that successfully completed Phase 1 were awarded Cooperative Agreements to conduct Phase 2 and 3 activities. These include:

- **Heart of Iowa Regional Transit Agency (HIRTA)**
  - Location: Dallas County, Iowa
  - Project: Health Connector for the Most Vulnerable: An Inclusive Mobility Experience from Beginning to End
  - Award: $2,872,549
- **Georgia Department of Transportation (GDOT)**
  - Location: Gwinnett County, Georgia
  - Project: Safe Trips in a Connected Transportation Network (ST-CTN)
  - Award: $8,051,200
- **University of Washington (UW)**
  - Location: Washington, Oregon, and Maryland
  - Project: Transportation Data Equity Initiative
  - Award: $9,659,000
- **Niagara Frontier Transportation Authority (NFTA)**
  - Location: Buffalo, New York
  - Project: Complete Trip Deployment in Buffalo, NY
  - Award: $6,666,981 V2X

## V2X Wireless Communications Summit

The U.S. DOT hosted a V2X Communications Summit on August 24 and 24, 2022. The Summit was held in-person at U.S. DOT headquarters in Southeast Washington, D.C., with the option for attendees to join virtually. At the Summit, ITS community stakeholders convened to provide information to U.S.DOT and support the development of a V2X communications deployment plan that optimizes benefits for the country.

The program included welcome remarks from ITS JPO Acting Director Egan Smith, an address from Deputy Assistant Secretary for Research & Technology and Chief Science Officer Dr. Robert Hampshire about the future of V2X deployment, and talks from several other U.S. DOT and industry staff. The Summit also included in-person and virtual breakout sessions on a variety of V2X communication topics.

V2X is communication between a vehicle and infrastructure, bicyclists, pedestrians, and other vehicles through cellular LTE. The U.S. DOT V2X communications deployment plan will foster a stable and inviting regulatory environment; establish V2X deployment targets and milestones; and facilitate deployment, research, and strategic preparedness.

## SMART Grants

The Bipartisan Infrastructure Law (BIL) of 2021 established the Strengthening Mobility and Revolutionizing Transportation (SMART) discretionary grant program with $100 million appropriated annually for fiscal years 2022¬-2026. The SMART program was established to provide grants to eligible public sector agencies to conduct projects focused on advanced smart community technologies and systems to improve efficiency and safety.

The U.S. DOT accepted applications for the SMART Grant awards from September 19, 2022, through November 18, 2022. Awards are expected to be announced in early 2023.

SMART

The Strengthening Mobility and Revolutionizing Transportation (SMART) grant program logo.

Photo Source: U.S. DOT

## ATTAIN Grants

In addition to the SMART Grant program, the BIL also established funding for the FHWA's Advanced Transportation Technology and Innovation (ATTAIN) program, also known as the Advanced Transportation Technologies and Innovative Mobility Deployment (ATTIMD) program. This program renamed and restructured the Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) program. The ATTAIN program will provide funding for eligible entities to develop model deployment sites for large scale operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment.

The U.S. DOT accepted applications for the ATTAIN Grants awards from September 19, 2022, through November 18, 2022. Awards are expected to be announced in early 2023.

## Smart Community Resource Center

In the fall of 2022, the ITS JPO launched the Smart Community Resource Center (SCRC) website. The SCRC is designed to connect States, Tribal governments, and local communities with resources that can be used to develop ITS and smart community transportation programs. Maintained by the ITS JPO, the SCRC is a database of smart community information and tools, deployment support resources, recent news and events, and U.S. DOT funding opportunities.

Smart communities use advanced information and communications technologies to find new ways to solve common problems like potholes, pollution, and traffic. These communities create an intelligent, integrated information network by applying sensors and wireless communications technologies to infrastructure, vehicles, wearables, and other physical devices. The SCRC offers the public the tools and resources necessary to deploy smart community technology nationwide.

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# KEY TRANSPORTATION LEGISLATION FUNDING BILLS

- **1956: The Federal-Aid Highway Act was signed.**
  - The act funded the creation of the U.S. interstate network.
  - The 41,000-mile system was planned to reach every metropolitan area with a population larger than 100,000.
- **1991: The Intermodal Surface Transportation Efficiency Act (ISTEA) was signed into law by President George H.W. Bush.**
  - ISTEA included a requirement that the U.S. DOT designate a federally utilized advisory committee to provide advice and assistance in the area of IVHS (ITS America was designated as the advisory committee).
  - ISTEA was the first transportation bill of the post-Interstate era and established policies that recognized the shift in focus from the building of a surface transportation system to the management and maintenance of that system.
  - The act encouraged the development and application of ITS advanced technologies to establish a safer and more efficient transportation system.
  - Under ISTEA, an IVHS Program was established, with approximately $660 million authorized for the 6-year authorization period.
- **1997: Transportation Equity Act for the 21st Century (TEA-21) was passed.**
  - TEA-21 retained ISTEA's essential features while boosting highway construction investments.
  - TEA-21 withdrew financial support from the National Automated Highway System Research Program (NAHSRP).
  - Through TEA-21, $1.282 billion was provided for fiscal years 1998 through 2003 to fund the ITS Program.
- **2005: Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law by President George W. Bush.**
  - The measure designated $286.4 billion to improve and maintain the surface transportation infrastructure in the United States.
  - In general, the bill continued the ITS research program as indicated in TEA-21, but modified the language to make technical changes and reflect new programmatic priorities.
  - SAFETEA-LU affirmed the growing return on ITS investment and contained provisions to embed ITS into the mainstream of transportation planning and deployment processes, as well as to increase general awareness of improved operations brought about by the adoption of ITS applications.
- **2012: Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into law by President Obama.**
  - MAP-21 funded surface transportation programs at over $105 billion for fiscal years 2013 and 2014 and created a performance-based surface transportation program that builds on many of the highway, transit, bike, and pedestrian programs and policies established in 1991 under ISTEA.
  - MAP-21 continues support for the ITS Program by restoring the ITS research budget to $100 million per year and establishing a Technology and Innovation Deployment program for $62.5 million per year. MAP-21 changed the focus of the use of funds for ITS activities by directing that the Secretary of Transportation encourage deployment of ITS technologies that will improve the performance of the national highway system.
- **2015: Fixing America's Surface Transportation (FAST) Act was signed into law by President Obama.**
  - The FAST Act established the Advanced Transportation and Congestion Management Technologies Deployment Program to make competitive grants for the development of model deployment sites for large-scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment.
- **2021: The Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act) was signed into law by President Biden**

# APPENDIX A. ACKNOWLEDGMENTS AND INTERVIEW TRACKER

## Acknowledgments

We would like to extend our appreciation to the following stakeholders for their support, collaboration, and contributions to the U.S. DOT ITS JPO over the years.

**AAA** - American Automobile Association

**AAMVA** - American Association of Motor Vehicle Administrators

**AASHTO** - American Association of State Highway and Transportation Officials

**Alliance of Automotive Manufacturers (Auto Alliance)**

**AMPO** - Association of Metropolitan Planning Organizations

**AMS** - American Meteorological Society

**APTA** - American Public Transportation Association

**ASTM** - American Society for Testing and Materials

**ATA** - American Trucking Associations

**Auto Care Association**

**CAMP** - Crash Avoidance Metrics Partnership

**CVTA** - Connected Vehicle Trade Association

**CTIA** - Cellular Telephone Industries Association

**CVSA** - Commercial Vehicle Safety Alliance

**GHSA** - Governors Highway Safety Association

**Global Alliance of Automakers**

**IBTTA** - International Bridge, Tunnel and Turnpike Association

**IEEE** - Institute of Electrical and Electronics Engineers

**ITS America** - Intelligent Transportation Society of America

**ITE** - Institute of Transportation Engineers

**NACE** - National Association of County Engineers

**NARC** - National Association of Regional Councils

**NEMA** - National Electrical Manufacturers Association

**NENA** - National Emergency Number Association

**NRITS** - National Rural Intelligent Transportation Systems

**OmniAir Consortium, Inc.**

**SAE** - Society of Automotive Engineers

**TRB** - Transportation Research Board

**TSAG** - Transportation Safety Advancement Group

## Interview Tracker

This report provides a brief yet comprehensive review of policies, research, technologies, and societal influences that have shaped the history and future of ITS. In researching and writing this report, it was critical to engage a number of ITS professionals and experts who truly understand how these developments unfolded. Throughout the research and drafting stages, the team engaged and interviewed a diverse group of individuals to ensure that this report captures the many facets of ITS.

The *History of ITS* development team would like to extend our appreciation and thanks to the following individuals that were instrumental in providing their input on the history and future of ITS.

| NAME | TITLE or CONTEXT | ORGANIZATION |
|---|---|---|
| PUBLIC SECTOR | | |
| Christine Johnson | Former Director | Intelligent Transportation Systems Joint Program Office |
| Shelley Row | Former ITS JPO Director | Shelley Row Associates, LLC |
| Richard Weingroff | Former Information Liaison Specialist and Unofficial Historian | Federal Highway Administration |
| Lyle Saxton | Retired Engineer | Turner-Fairbank Highway Research Center |
| Robert E. Skinner, Jr. | Former Director of the Transportation Research Board | Transportation Research Board |
| Jane Lappin | Chairperson, Standing Committee on Road Vehicle Administration | Transportation Research Board |
| Bob Johns | Former Associate Administrator and Director | Volpe National Transportation Systems Center |
| Suzanne Sloan | Principal Technical Advisor, Technology Innovation and Policy | Volpe National Transportation Systems Center |
| Mark Norman | Director, Development and Strategic Initiatives | Transportation Research Board |
| James Pol | Technical Director, Office of Safety Research and Development | Federal Highway Administration |
| Paul Pisano | Former Team Leader, Road Weather and Work Zone Management | Federal Highway Administration |
| Mac Lister | Program Manager (Retired) | Federal Highway Administration |

| NAME | TITLE or CONTEXT | ORGANIZATION |
|---|---|---|
| Jeff Loftus | Chief, Technology Division | Federal Motor Carrier Safety Administration |
| Jeff Spencer | Community Planner | Federal Aviation Administration |
| Collin Castle | Connected Vehicle Technical Manager | Michigan Department of Transportation |
| Brian Cronin | Director, Office of Operations Research | Federal Highway Administration |
| John Harding | Connected/Automated Vehicles and Emerging Technologies Team | Federal Highway Administration |
| Robert Bertini | Head of the School of Civil and Construction Engineering | Oregon State University |
| PRIVATE SECTOR | | |
| Jim Barbaresso | Senior Vice President (Retired) | HNTB Corporation |
| Steve Lockwood | President | Lockstep Consulting, LLC |
| Jim Misener | Senior Director, Product Management | Qualcomm |
| Bill Spreitzer | Technical Director (Retired) | General Motors |
| Jim Wright | Former President | James Wright Consulting |
| ASSOCIATIONS | | |
| Richard Bishop | Principal and Owner | Bishop Consulting |
| Jim Constantino | Former President and CEO | ITS America |
| John Collins | Former President and CEO | ITS America |
| Scott McCormick | President; ITS Program Advisory Committee | Connected Vehicle Trade Association |
| ACADEMIA | | |
| Steve Shladover | Research Engineer | University of California, Berkeley |
| Jonathan Gifford | Director, Center for Transportation Public-Private Partnership Policy School of Policy, Government, and International Affairs | George Mason University |

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