Automation

ITS Benefits, Costs, and Lessons Learned: 2017 Update Report

U.S. Department of Transportation

Photo Source: USDOT

Automated Vehicles

Highlights

- Within the next 10 years it is likely that autonomous vehicles will be available to the general public.
- Automated vehicles can save more than 1000 lives annually with 10 percent market penetration.
- Autonomous vehicles, if fully deployed, can use intelligent intersections to manage approach speeds and reduce fuel consumption and emissions up to 50 percent.
- Self-driving capabilities will likely add several thousand dollars to a vehicle's purchase price.

Introduction

This factsheet is based on past evaluation data contained in the ITS Knowledge Resources database at: www.itskrs.its.dot.gov. The database is maintained by the U.S. DOT's ITS JPO Evaluation Program to support informed decision making regarding ITS investments by tracking the effectiveness of deployed ITS. The factsheet presents benefits, costs and lessons learned from past evaluations of ITS projects.

Autonomous vehicles also known as self-driving, driverless, or robotic vehicles are defined as computer-equipped vehicles that can be driven and operated without active control by a human driver. Using integrated sensor systems, complex algorithms, and automated vehicle (AV) technology, autonomous vehicles can plan routes, navigate through traffic, negotiate lane changes and turns, manage speeds, and assist with parking. With AV technology, a variety of new functions are expected over the next several years as connected vehicle (CV) applications are refined and implemented in accordance with governmental regulations and controls.

While not required for autonomous driving, CV applications are expected to enhance the operational capacity of autonomous vehicles networks and bring about a variety of benefits such as improved situational awareness for increased safety, improved fuel economy, reduced parking needs, and increased mobility for those unable to drive. To help realize these benefits, the United States Department of Transportation (USDOT) Intelligent Transportation Systems Joint Program Office (ITS JPO) has made Advancing Automation a key strategic priority.

Photo Source: USDOT

As preliminary guidance, the National Highway Traffic Safety Administration (NHTSA) established the following framework that defines five levels of automation. [1]

- **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.
- **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.
- **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 while driving in those conditions, rely heavily on the vehicle to monitor for changes requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time.
- **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 is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

Photo Source: USDOT

The design of an autonomous vehicle can vary greatly depending on the level of automation needed, but in general includes the following components.

- **Sensors**
  - **Lidar** – Light detection and ranging (Lidar) sensors measure distance (50-100 meters) between the vehicle and nearby objects by emitting pulses of light from multiple rotating laser beams at a rate of more than one million measurements per second creating a 3D model of the space surrounding the vehicle accurate to approximately one centimeter.
  - **Radar** – Radio detection and ranging (Radar) sensors measure distance (60-200 meters) between the vehicle and nearby objects located in front and back of the vehicle using directional wave radio signals.
  - **Ultrasonic** – Ultrasonic sensors measure short distances (0-5 meters) between the sides or rear of a vehicle and nearby objects.
  - **Cameras** – Cameras with streaming picture processing technology can gauge distances between the vehicle and other vehicles, read signs, and detect pedestrians.
- **Navigation** – In-vehicle navigation systems can use GPS, sensor enhanced maps, and positional information from ground-based radio beacons to support navigation under a variety of conditions.
- **Computing hardware and software** – Powerful computers and advanced algorithms can manage automated features using redundant control logic. User interfaces can support smooth transitions between different levels of automated control.
- **Mechanical controllers and actuators** – Automated control of brakes, throttle, steering, gear selection, and secondary controls (i.e., turn signals, hazard lights, headlights, door locks, ignition, and horn) will incorporate redundancy for safe operation and use reliable power supplies.
- **Wireless communications** – Dedicated Short Range Communications (DSRC) along with mobile communication networks, can support a wide variety of CV and AV applications.

Although autonomous vehicles do not require wireless connectivity to operate, transportation agencies will likely need CV applications to effectively manage operations in the future. Thus, over the past several years the federal government and industry have focused heavily on developing guidance and standards for developing CV systems to assure that future applications will be safe and interoperable. AV technology, however, has evolved outside the scope of government oversight. Driven by market forces automakers and industry have discovered new opportunities to expand into growing AV technology markets. Industry experts and government agencies now agree that within the next 10 years it is likely that autonomous vehicles will be available to the general public and industry standards will be in place to support CV applications nationwide.

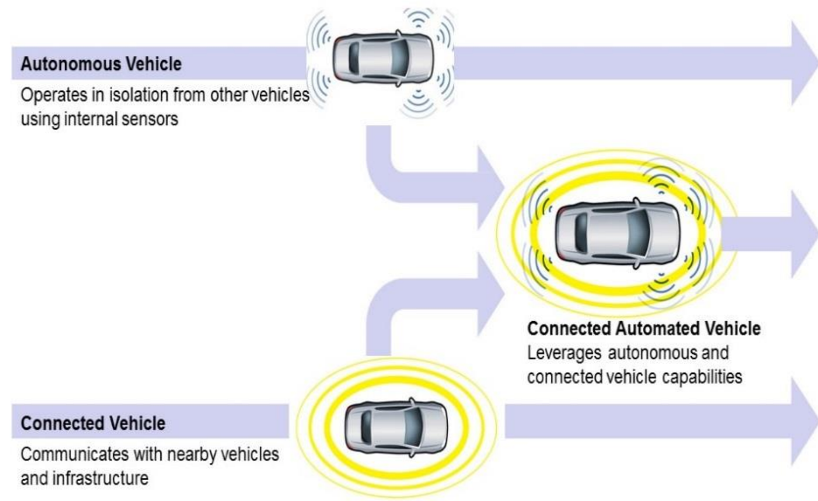

Figure 1: Integration of CV and AV Technologies
(Source: USDOT)

Recent initiatives such as WAYMO (previously known as the Google self-driving car project) have shown substantial progress. Since 2009, 23 of its self-driving cars have driven over one million miles on public roads in Texas and California proving that autonomous vehicles can be safe if not safer than human drivers who on average cause a motor vehicle crash every 165,000 miles (assuming an average driver travels up to 16,500 miles per year and reports a crash claim every 10 years). [2, 3] Although autonomous vehicles will need to be driven hundreds of millions of miles or more to fully assess their reliability, there is great potential for positive safety impacts. Motor vehicle crashes in the United States have social and economic costs of about $800 billion per year, 70 to 90 percent of which are attributable to human error. [4, 5]

A number of automakers continue to develop and implement AV technology. In October 2015, Tesla released a prototype of its Autopilot system designed to automate control of both speed and steering functions. Autopilot is expected to be the first system with Level 2 automation made available to the general public in the United States.

Benefits

Available research indicates that autonomous vehicles operating on CV networks can reduce fuel consumption up to 50 percent, decrease emissions 39 to 50 percent, decrease travel times 12 to 48 percent, reduce delays up to 85 percent, and save thousands of lives each year.

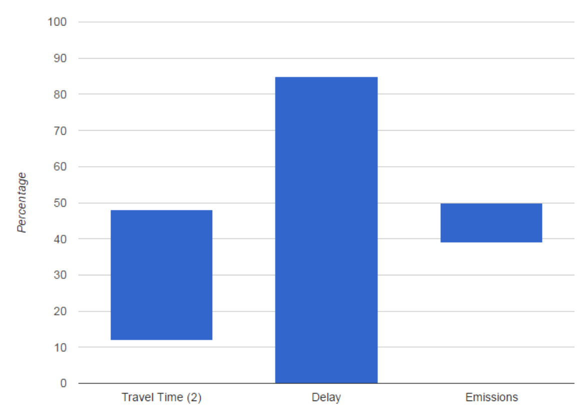

Figure 1: Automation Benefits Range (Source: ITS Knowledge Resources)

Automated vehicles can save more than 1000 lives annually with 10 percent market penetration.

Costs

The incremental costs of manufacturing autonomous vehicles will vary depending on the system configuration, maturity of technology, and the likelihood that system components will be less expensive with economies of scale. In order to earn profits, manufacturers will need to meet high manufacturing, installation, repair, testing, and maintenance standards (similar to those required for aircraft) and manage any risks associated with liability. As the technology matures, self-driving capabilities will likely add several thousand dollars to a vehicle's purchase price and require a few hundred dollars each year in additional maintenance. (2015-00356)

Case Study – Preparing a Nation for Autonomous Vehicles (2015-00977)

As part of a research project conducted to assess potential benefits and impacts of autonomous vehicles with respect to traffic safety, congestion, and travel behaviors, a literature review was conducted to estimate and monetize traveler benefits in the form of crash and congestion reduction, and parking savings across multiple levels of market penetration. Researchers not only examined the capabilities of individual autonomous vehicles, but also the impacts of autonomous vehicle operations within an environment of increasing connectivity among vehicles and infrastructure systems.

Findings

Data gathered from the source report show that impacts will vary greatly depending on market penetration. Congestion benefits are expected to be realized first, followed by increasing safety benefits as the technology matures and market penetration levels increase.

Table 1: Benefits and Costs of Autonomous Vehicles with Increasing Market Share
(Source: ITS Knowledge Resources)

	10% Market Share	50% Market Share	90% Market Share
Crash Cost Savings from Autonomous Vehicles			
Lives Saved (per year)	1,100	9,600	21,700
Fewer Crashes	211,000	1,880,000	4,220,000
Economic Cost Savings	$5.5 billion	$48.8 billion	$109.7 billion
Comprehensive Cost Savings	$17.7 billion	$158.1 billion	$355.4 billion
Economic Cost Savings per Autonomous Vehicle	$460	$1,080	$1,690
Comprehensive Cost Savings per Autonomous Vehicle	$1,470	$3,500	$5,460
Congestion Costs			
Travel Time Savings (Hours)	756 million	1680 million	2772 million
Fuel Savings (Gallons)	102 million	224 million	724 million
Total Savings	$16.8 billion	$37.4 billion	$63.0 billion
Savings per Autonomous Vehicle	$1,400	$830	$970

Overall Impacts			
Annual Savings: Economic Costs Only	$25.3 billion	$97.5 billion	$189.0 billion
Annual Savings: Comprehensive Costs	$37.6 billion	$206.8 billion	$434.7 billion
Savings Per Autonomous Vehicle: Economic Costs Only	$2,110	$2,160	$2,910
Savings Per Autonomous Vehicle: Comprehensive Costs	$3,120	$4,580	$6,680
Net Present Value of Autonomous Vehicle Benefits minus Purchase Price: Economic Costs Only	$6,050	$11,430	$19,130
Net Present Value of Autonomous Vehicle Benefits minus Purchase Price: Comprehensive Costs	$13,730	$29,840	$47,810
Assumptions			
Number of Autonomous Vehicles Operating in U.S.	0.5	0.75	0.9
Freeway Congestion Benefit (delay reduction)	5%	10%	15%
Arterial Congestion Benefit	13%	18%	25%
Fuel Efficiency Benefit	8%	13%	13%
Non-Autonomous Vehicle Following-Vehicle Fuel Efficiency Benefit (Freeway)	20%	15%	10%
VMT Increase per Autonomous Vehicle	10%	10%	10%
% of Autonomous Vehicles Shared across Users	10%	10%	10%
Added Purchase Price for Autonomous Vehicle Capabilities	$10,000	$5,000	$3,000
Discount Rate	10%	10%	10%
Vehicle Lifetime (years)	15	15	15

*Comprehensive Costs also include the statistical value of life, and pain and suffering.

References

[1] "U.S. DOT Releases Policy on Automated Vehicle Development," USDOT NHTSA, Briefing No. 14-13. 30 May 2013.

[2] "Average Annual Miles per Driver by Age Group," USDOT FHWA OIP, Webpage https://www.fhwa.dot.gov/ohim/onh00/bar8.htm. Accessed 13 February 2017.

[3] *America's Best Drivers Report*. Allstate Insurance Company. 2016.

[4] Blincoe, et.al. *The Economic and Societal Impact of Motor Vehicle Crashes 2010 (Revised)*, USDOT NHTSA, Report No. HS 812 013. May 2015.

[5] *The Changing Face of Transportation*. USDOT, Report No. BTS00-007. 2000.

All other data referenced is available through the ITS Knowledge Resources Database, which can be found at http://www.itsknowledgeresources.its.dot.gov/.

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