DKS Experts Connecting Communities

Connected & Autonomous Vehicles

Today's Transportation Challenges

Safety

33,561 highway deaths in 2012
5,615,000 crashes in 2012
Leading cause of death for ages 4, 11-27

Mobility

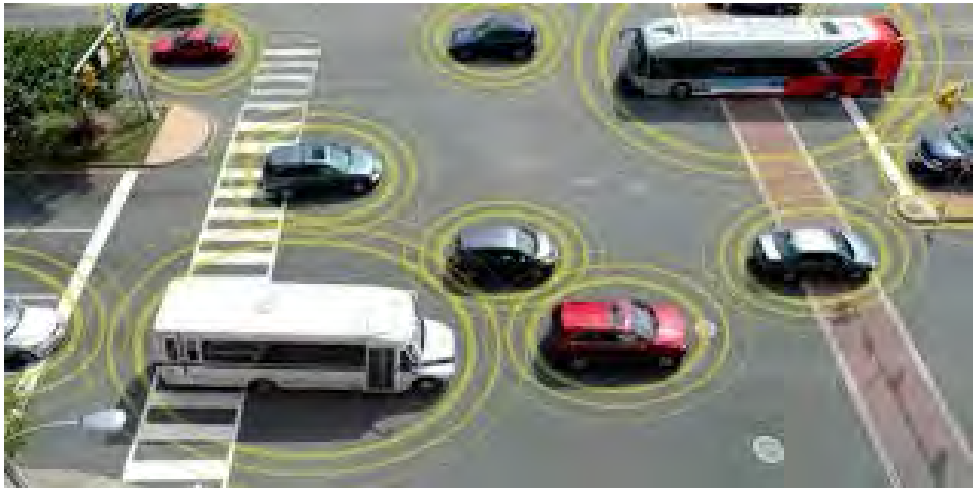
5.5 billion hours of travel delay
$121 billion cost of urban congestion

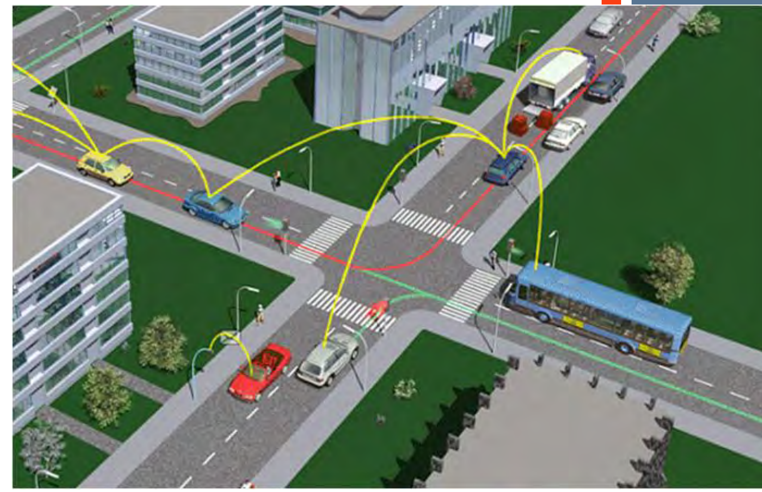
Environment

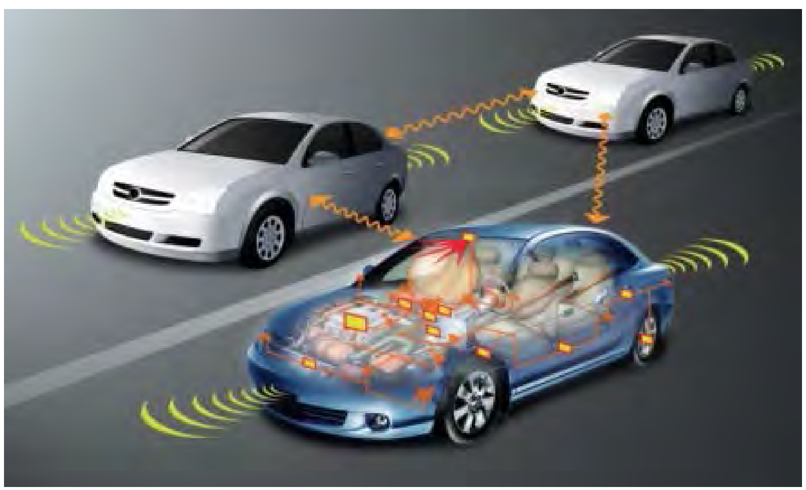
2.9 billion gallons of wasted fuel
56 billion lbs. of additional CO_2

- Connected Vehicles have the potential of addressing approximately 80% of the vehicle crash scenarios involving unimpaired drivers!
- NHTSA – Connected Vehicles provide foundation to saving lives

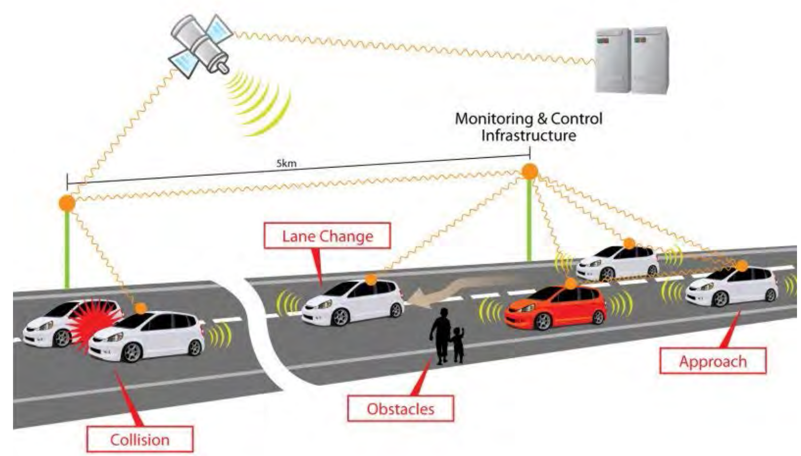
V2X: Vehicle to What?





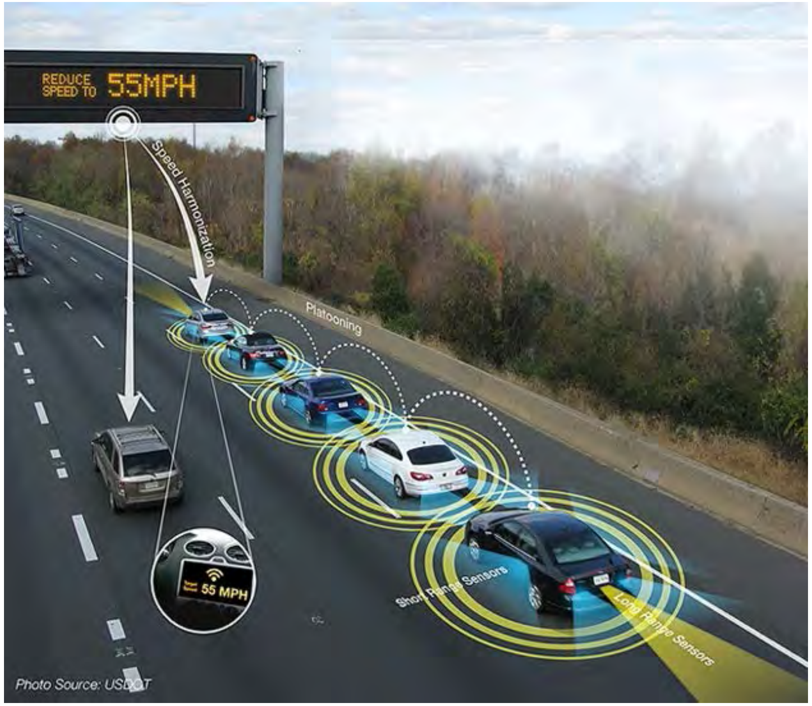


V2V: Vehicle-to-Vehicle



V2I: Vehicle-to-Infrastructure

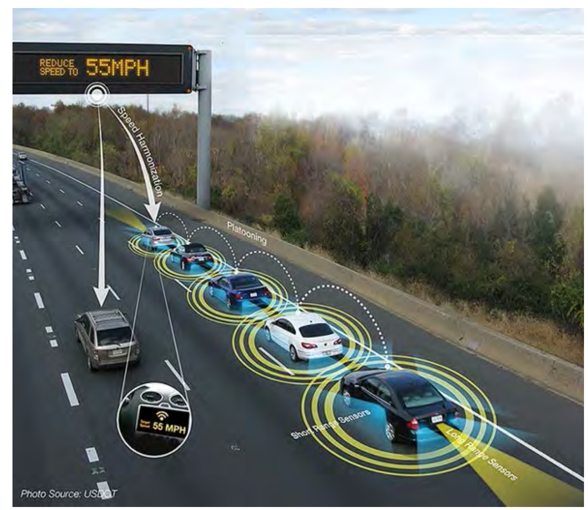
Connected vs. Autonomous



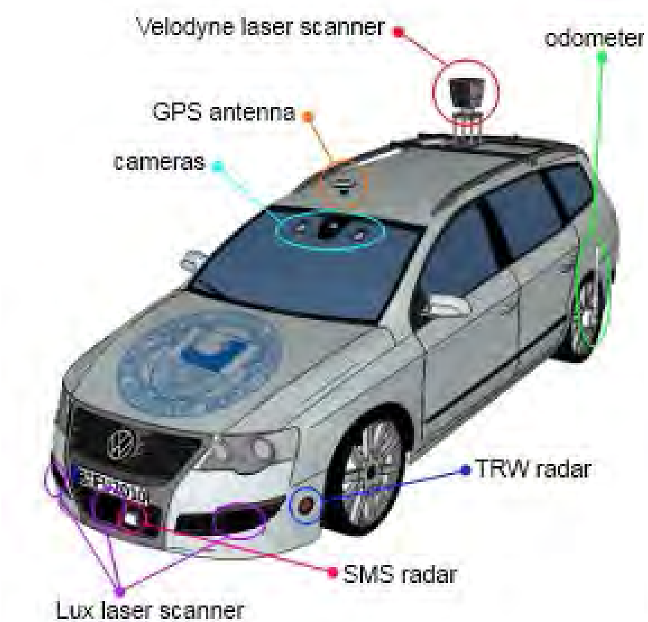
Autonomous will be Connected

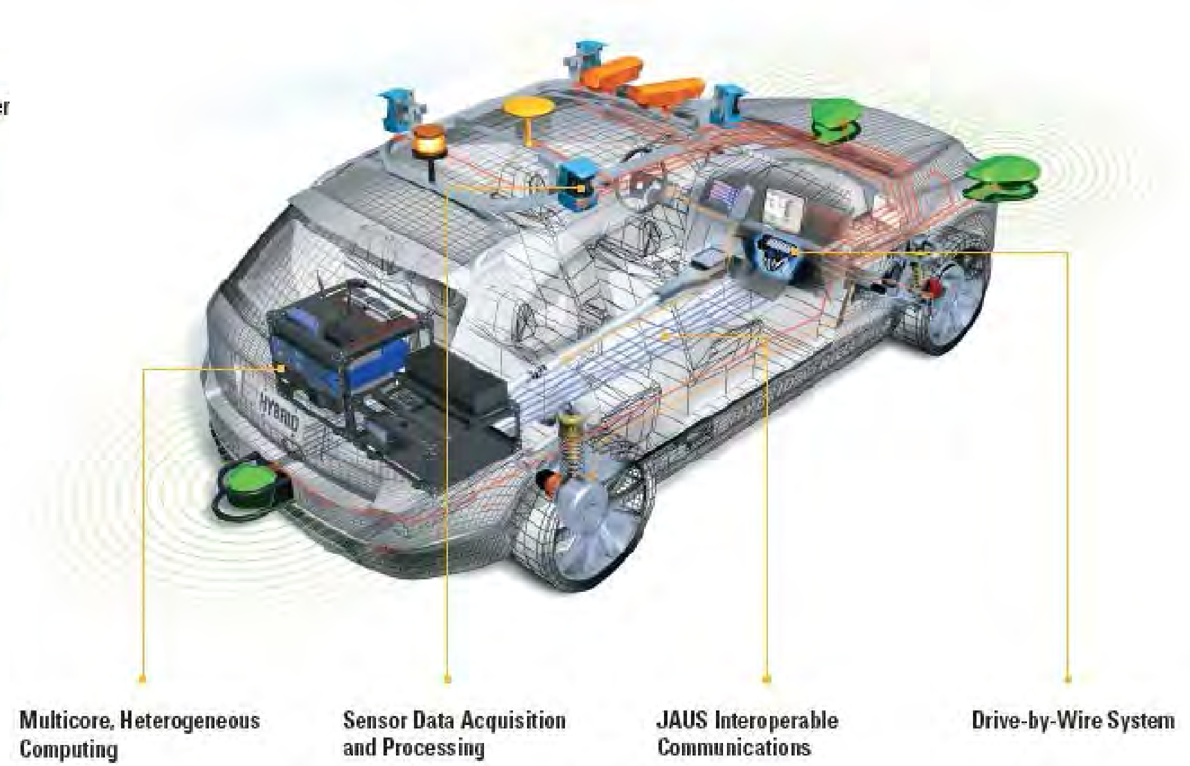
Connected Vehicles

Autonomous Vehicles

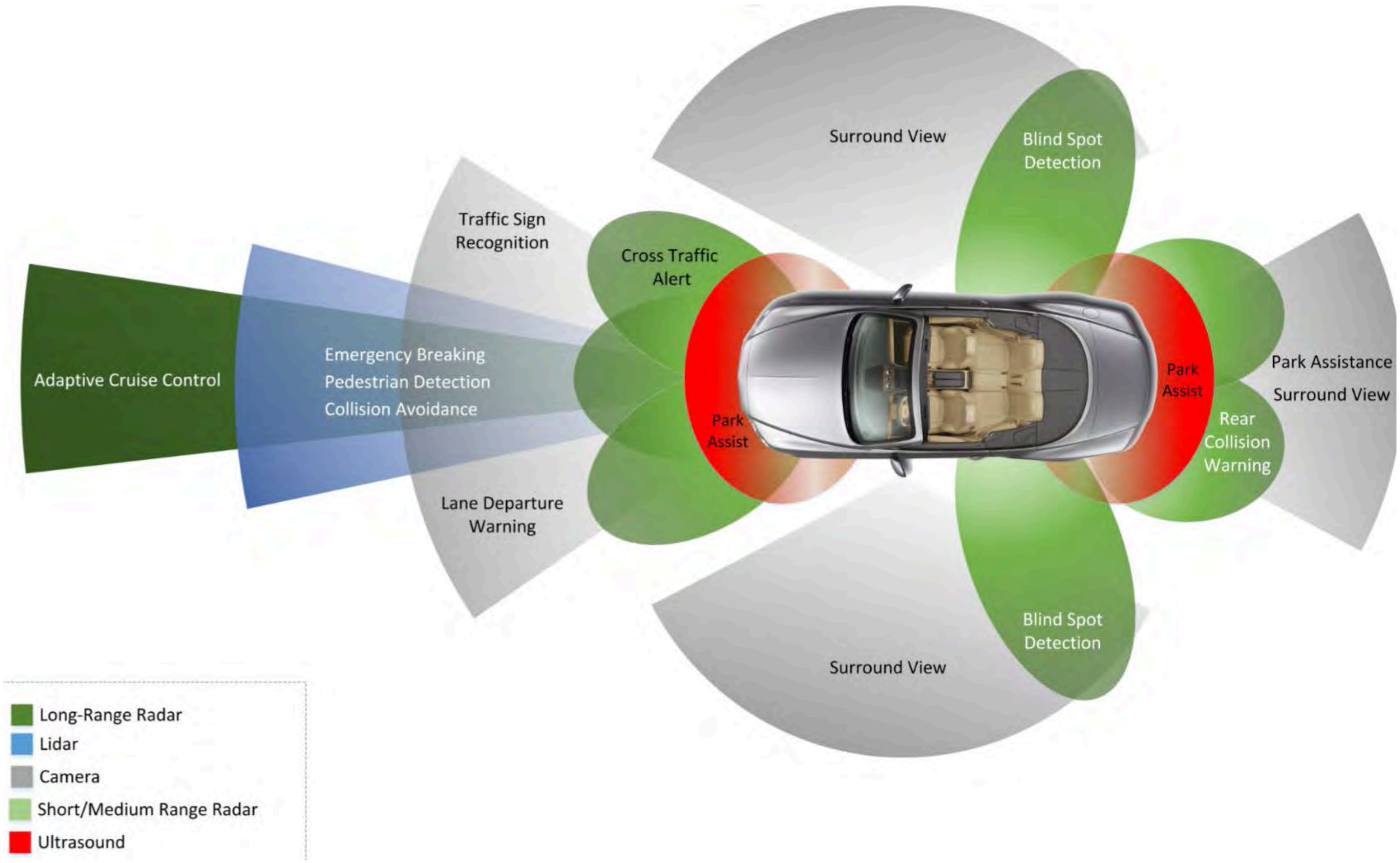


What makes Autonomous work?





Sensors and Cameras Everywhere



NHTSA Defined Levels of Automation

- **No-Automation (Level 0):** The driver is in complete and sole control.
- **Function-specific Automation (Level 1):** Automation at this level involves one or more specific control functions.
- **Combined Function Automation (Level 2):** 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.
- **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.

NHTSA Defined Levels (detailed)

- **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.

NHTSA Defined Levels (detailed)

- **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 is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

Tesla's Migration Plan

2015 Tesla 'Autopilot' (Autonomous 2023)

'will go from on-ramp to off-ramp autonomously'

Special thanks to Randy Iwasaki from Contra Costa County Transportation Authority

Rethinking the Layout of the Car

2015 Mercedes Benz F 015 Concept

“Innovative perspective into the future of mobility.”

Trucks May Be Some of the Earliest

Mercedes Benz Future Truck 2025

Many technological elements already available

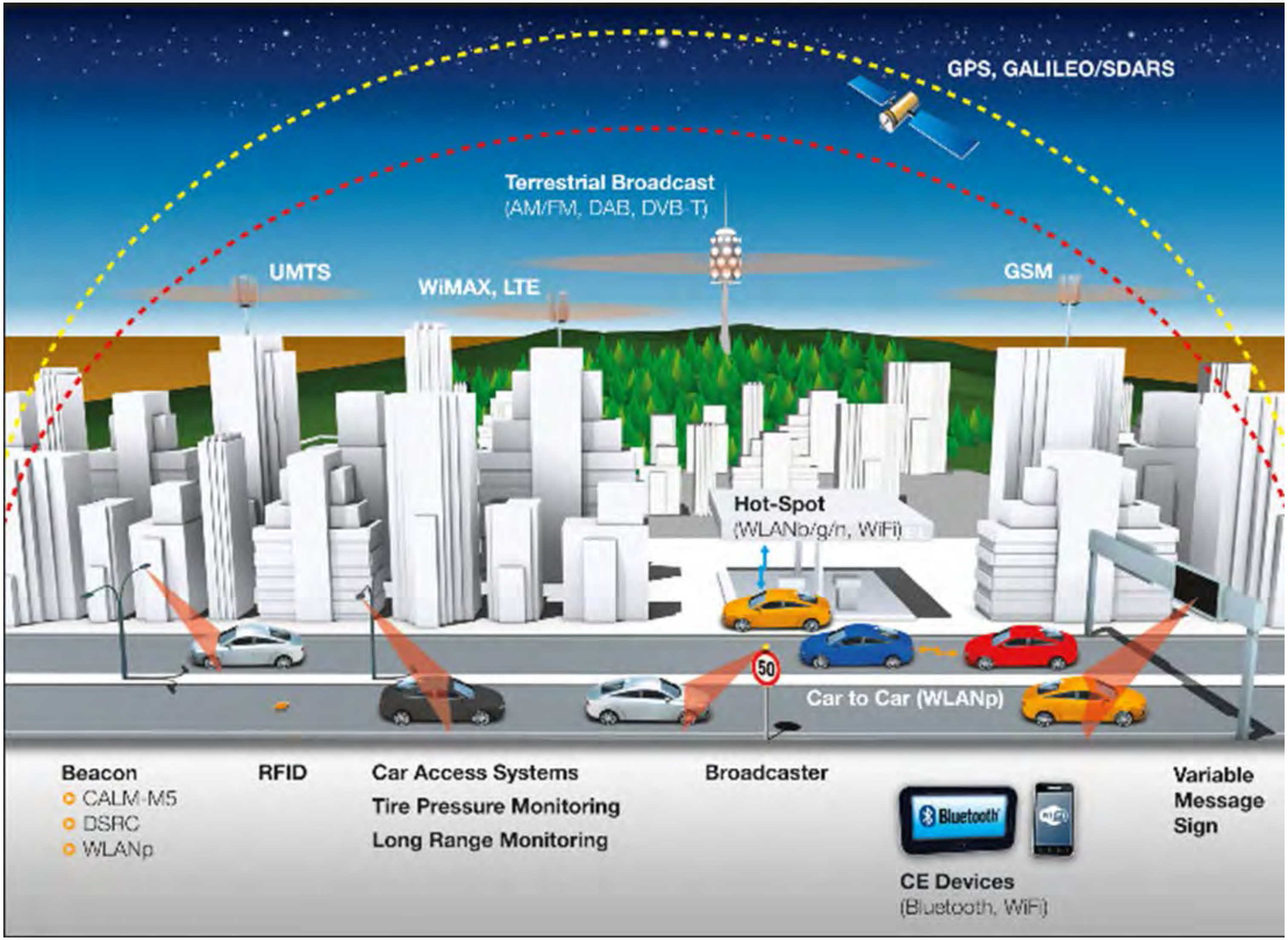
V2 – What? (Beyond V2V and V2I)

- Vehicle to Central Systems & Service Providers (V2X)
- Vehicle to "nomadic travelers" – Pedestrians, bicyclist, motorcyclists (V2X)

DSRC ≠ Connected Vehicles

- Dedicated Short Range Communications
- What is it?
  - Special Wi-Fi radio (802.11p) adapted for high speed environment
    - Very short latency times – well suited for Safety Applications
    - Provides ad hoc communications
  - NA Frequency 5.9GHz – EU/Asia 5.8GHz
    - Dedicated frequency set aside by FCC – local agency license
    - 75 MHz of dedicated Spectrum
  - Relatively inexpensive in production quantities

Lots of ways to connect



Connected Vehicle Application Research

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V2I Safety

Red Light Violation Warning
Curve Speed Warning
Stop Sign Gap Assist
Spot Weather Impact Warning
Reduced Speed/Work Zone Warning
Pedestrian in Signalized Crosswalk Warning (Transit)

V2V Safety

Emergency Electronic Brake Lights (EEBL)
Forward Collision Warning (FCW)
Intersection Movement Assist (IMA)
Left Turn Assist (LTA)
Blind Spot/Lane Change Warning (BSW/LCW)
Do Not Pass Warning (DNPW)
Vehicle Turning Right in Front of Bus Warning (Transit)

Agency Data

Probe-based Pavement Maintenance
Probe-enabled Traffic Monitoring
Vehicle Classification-based Traffic Studies
CV-enabled Turning Movement & Intersection Analysis
CV-enabled Origin-Destination Studies
Work Zone Traveler Information

Environment

Eco-Approach and Departure at Signalized Intersections
Eco-Traffic Signal Timing
Eco-Traffic Signal Priority
Connected Eco-Driving
Wireless Inductive/Resonance Charging
Eco-Lanes Management
Eco-Speed Harmonization
Eco-Cooperative Adaptive Cruise Control
Eco-Traveler Information
Eco-Ramp Metering
Low Emissions Zone Management
AFV Charging / Fueling Information
Eco-Smart Parking
Dynamic Eco-Routing (light vehicle, transit, freight)
Eco-ICM Decision Support System

Road Weather

Motorist Advisories and Warnings (MAW)
Enhanced MDSS
Vehicle Data Translator (VDT)
Weather Response Traffic Information (WxTINFO)

Mobility

Advanced Traveler Information System
Intelligent Traffic Signal System (I-SIG)
Signal Priority (transit, freight)
Mobile Accessible Pedestrian Signal System (PED-SIG)
Emergency Vehicle Preemption (PREEMPT)
Dynamic Speed Harmonization (SPD-HARM)
Queue Warning (Q-WARN)
Cooperative Adaptive Cruise Control (CACC)
Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
Emergency Communications and Evacuation (EVAC)
Connection Protection (T-CONNECT)
Dynamic Transit Operations (T-DISP)
Dynamic Ridesharing (D-RIDE)
Freight-Specific Dynamic Travel Planning and Performance
Drayage Optimization

Smart Roadside

Wireless Inspection
Smart Truck Parking

What is already happening in the automotive industry?

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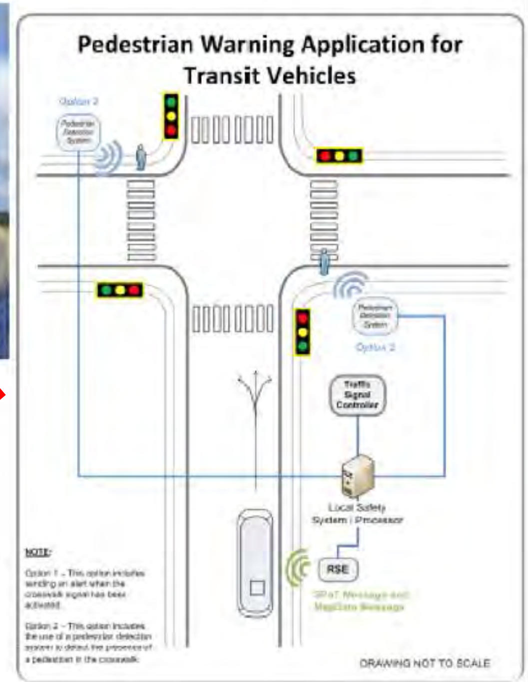
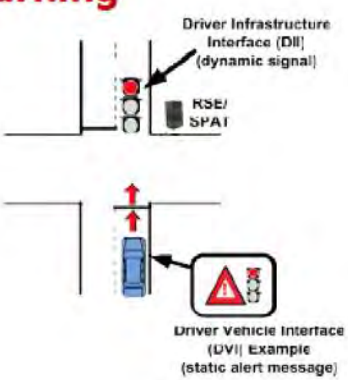
Early V2I Applications

Curve Speed Warning

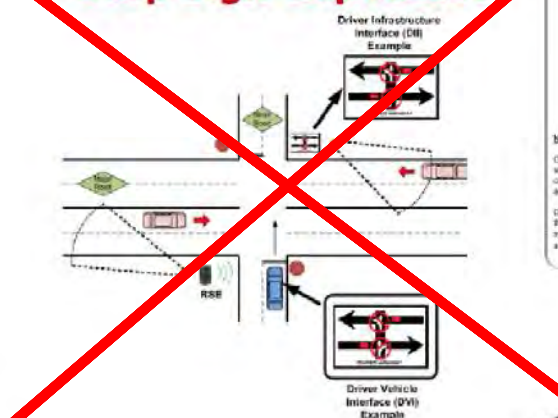
Smart Roadside



Red Light Violation Warning



~~Stop Sign Gap Assist~~



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Video Time

- USDOT Infrastructure & Application Focused
- http://www.its.dot.gov/library/media/15cv_future.htm

- AT&T: Customer Focused
- https://www.youtube.com/watch?v=uoZHPZ1CXkk

Why Should Agencies Care About CAVs?

- Planning Answer
  - Particular focus on Autonomous Vehicles
  - Because they are coming and the will change the way the transportation network is utilized
- Engineering Answer
  - Particular focus on Connected Vehicles
  - Because they are coming and infrastructure will be needed to support them
  - When Autonomous Vehicles get more connected, they will be one in the same
- Everybody Answer
  - We will all be dealing with a mixed fleet for some time
  - Timeline (next slide), safety/mobility/environment

Timeline for Connected Vehicles

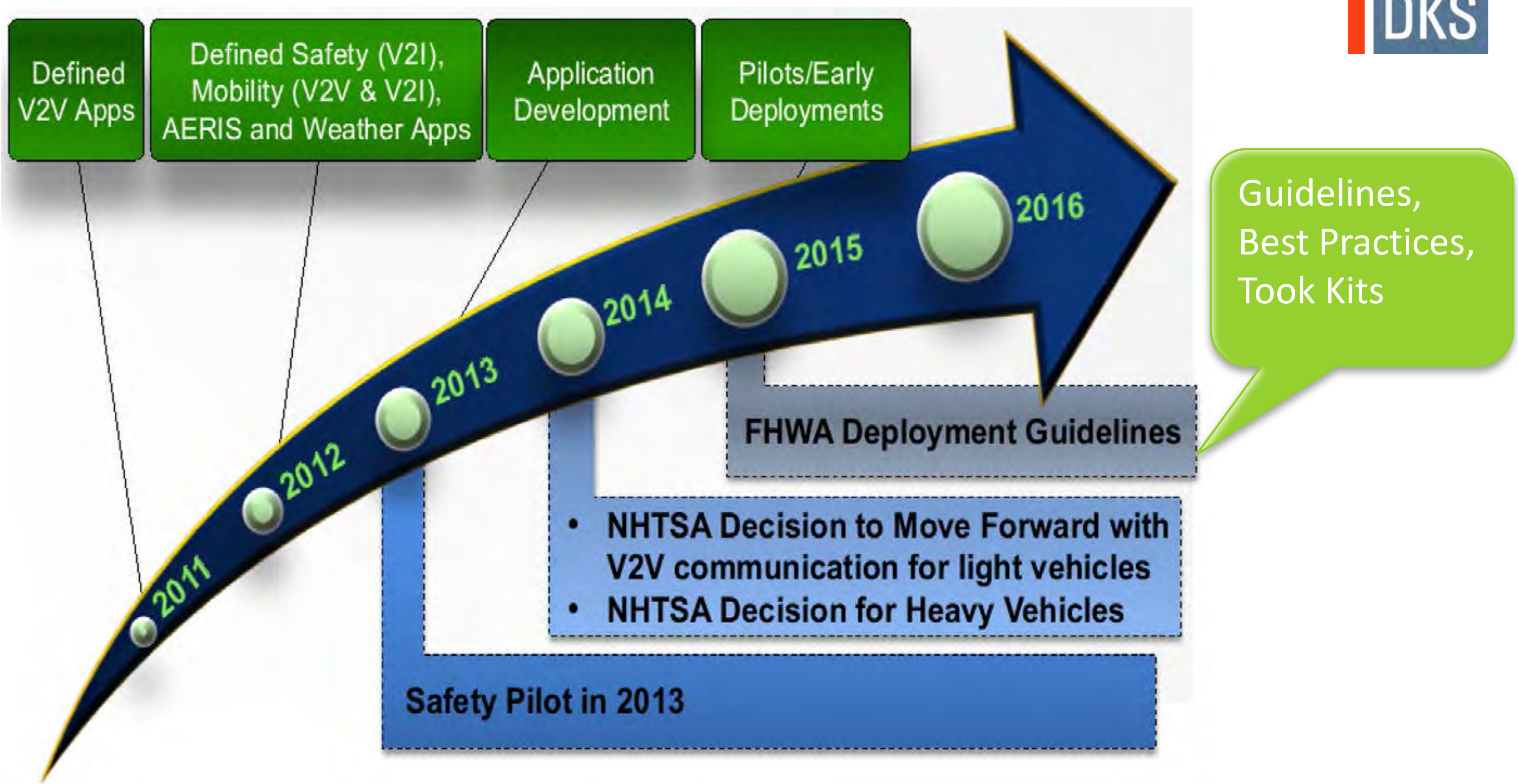


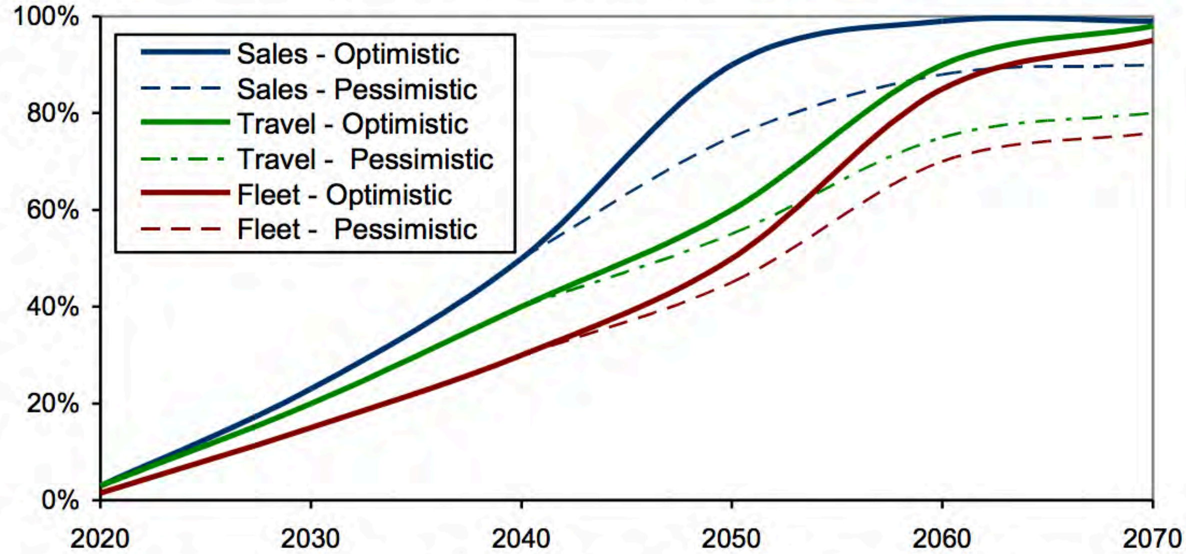
Table 6 **Autonomous Vehicle Implementation Projections**

Stage	Decade	Vehicle Sales	Veh. Fleet	Veh. Travel
Available with large price premium	2020s	2-5%	1-2%	1-4%
Available with moderate price premium	2030s	20-40%	10-20%	10-30%
Available with minimal price premium	2040s	40-60%	20-40%	30-50%
Standard feature included on most new vehicles	2050s	80-100%	40-60%	50-80%
Saturation (everybody who wants it has it)	2060s	?	?	?
Required for all new and operating vehicles	???	100%	100%	100%

Autonomous vehicle implementation will probably take several decades.

Autonomous Vehicle Projections

Figure 1 **Autonomous Vehicle Sales, Fleet and Travel Projections** (Based on Table 6)



If autonomous vehicle implementation follows the patterns of other vehicle technologies it will take one to three decades to dominate vehicle sales, plus one or two more decades to dominate vehicle travel, and even at market saturation it is possible that a significant portion of vehicles and vehicle travel will continue to be self-driven, indicated by the dashed lines.

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Why Should Everybody Care About CAVs?

Safety

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5,615,000 crashes in 2012
Leading cause of death for ages 4, 11-27

Mobility

5.5 billion hours of travel delay
$121 billion cost of urban congestion

Environment

2.9 billion gallons of wasted fuel
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Why Should Everybody Care About CAVs?

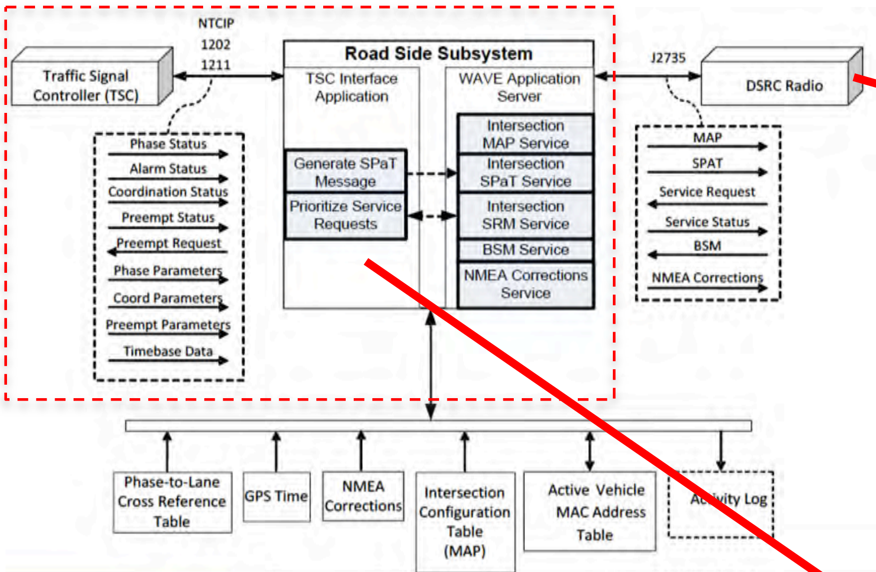
- Increased Safety
  - Reduced crashes
  - Workzone safety
- Improved Traffic Flow
  - Incidents cause significant congestion
  - Off peak and more remote areas
- Improved Air Quality
  - Improved throughput reduces idling
  - Especially when combined with transition to hybrid and fully electric
- Open Discussion?

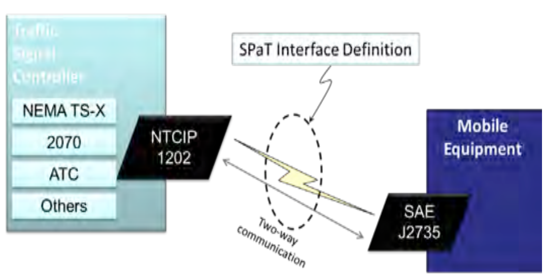
What are the requirements for CAVs?

What can we do to get ready for CAVs?

- Planning Answer
  - Particular focus on Autonomous Vehicles
  - Get educated about the impacts
  - Start incorporating into plans & introduce more agility and flexibility
- Engineering Answer
  - Particular focus on Connected Vehicles (see comment before about why)
  - The key right now is to support flexibility and don’t “preclude” the ability to support technology

V2I Intersection Architecture





How Can Public Agencies Move Forward?

- Roundtable Discussion
  - Planning perspective
  - Engineering/Operations perspective
  - Collaboration with Oregon and Portland Metro area
- Direction for VAST?

Good Resources:

https://www.pcb.its.dot.gov/eprimer/module13.aspx

http://www.vtpi.org/avip.pdf

DSRC Threat

- In 1997 the FCC allocated the frequency spectrum of 5.9GHz specifically to transportation applications
- Two bills are now before congress that propose opening up the 5.9GHz band four unlicensed WiFi use. This potentially poses a threat to the use of DSRC for safety applications.
- ITS America and others have petitioned the FCC to and Congress to delay any action by the FCC until testing can show the DSRC for Connected Vehicles will not be impacted by opening the 5.9 GHz spectrum space to unlicensed us.

Table 1 **Autonomous Vehicle Potential Benefits and Costs**

Benefits	Costs/Problems
Reduced driver stress. Reduce the stress of driving and allow motorists to rest and work while traveling.	*Increases costs.* Requires additional vehicle equipment, services and maintenance, and possibly roadway infrastructure.
Reduced driver costs. Reduce costs of paid drivers for taxis and commercial transport.	*Additional risks.* May introduce new risks, such as system failures, be less safe under certain conditions, and encourage road users to take additional risks (offsetting behavior).
Mobility for non-drivers. Provide independent mobility for non-drivers, and therefore reduce the need for motorists to chauffeur non-drivers, and to subsidize public transit.	*Security and Privacy concerns.* May be used for criminal and terrorist activities (such as bomb delivery), vulnerable to information abuse (hacking), and features such as GPS tracking and data sharing may raise privacy concerns.
Increased safety. May reduce many common accident risks and therefore crash costs and insurance premiums. May reduce high-risk driving, such as when impaired.	*Induced vehicle travel and increased external costs.* By increasing travel convenience and affordability, autonomous vehicles may induce additional vehicle travel, increasing external costs of parking, crashes and pollution.
Increased road capacity, reduced costs. May allow platooning (vehicle groups traveling close together), narrower lanes, and reduced intersection stops, reducing congestion and roadway costs.	*Social equity concerns.* May have unfair impacts, for example, by reducing other modes' convenience and safety.
More efficient parking, reduced costs. Can drop off passengers and find a parking space, increasing motorist convenience and reducing total parking costs.	*Reduced employment and business activity.* Jobs for drivers should decline, and there may be less demand for vehicle repairs due to reduced crash rates.
Increase fuel efficiency and reduce pollution. May increase fuel efficiency and reduce pollution emissions.	*Misplaced planning emphasis.* Focusing on autonomous vehicle solutions may discourage communities from implementing conventional but cost-effective transport projects such as pedestrian and transit improvements, pricing reforms and other demand management strategies.
Supports shared vehicles. Could facilitate carsharing (vehicle rental services that substitute for personal vehicle ownership), which can provide various savings.	

Autonomous vehicles can provide various benefits and impose various costs.

Autonomous Vehicle Implementation Predictions: Implications for Transport Planning
Victoria Transport Policy Institute

DKS