Michael Baker
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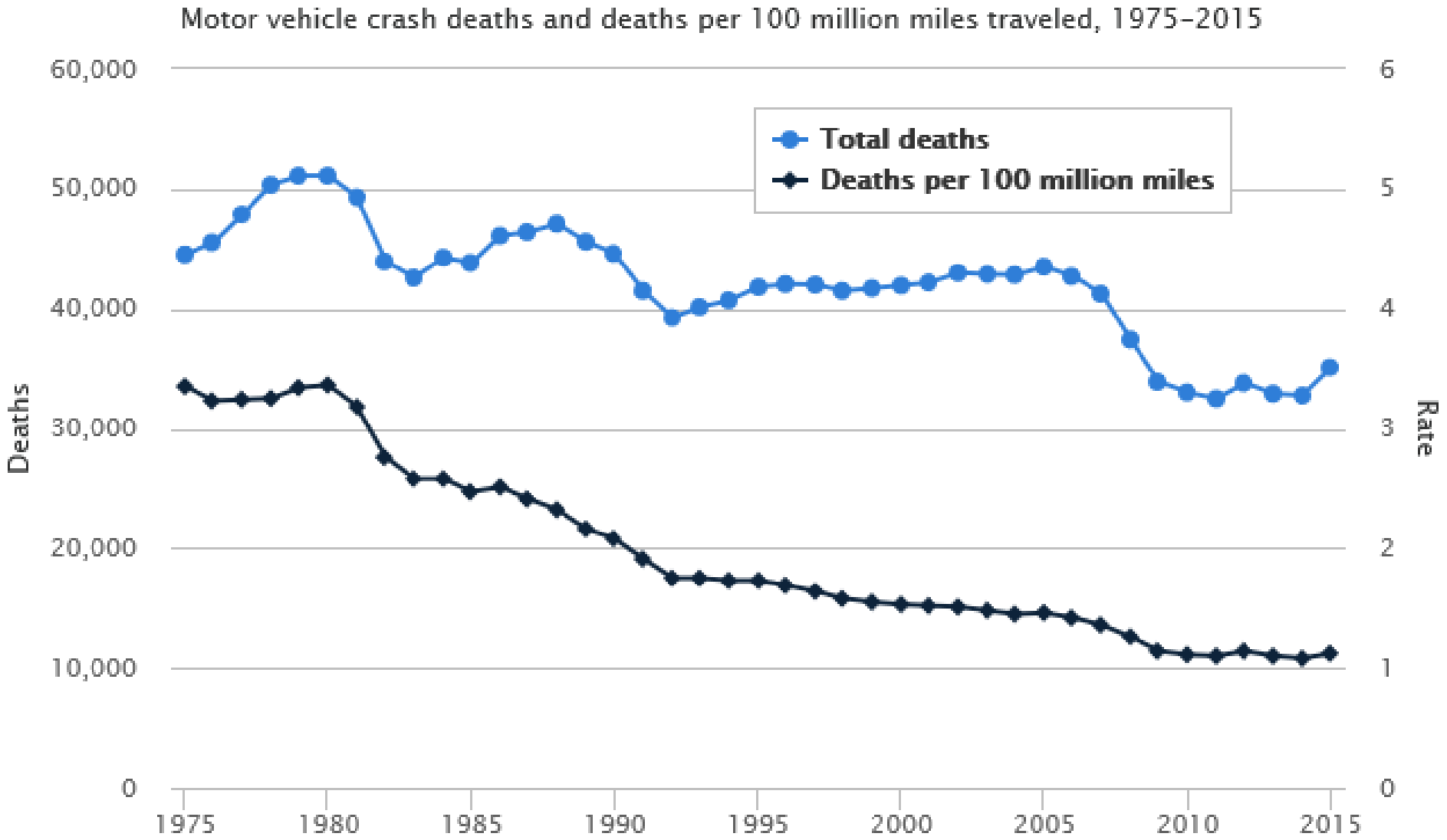
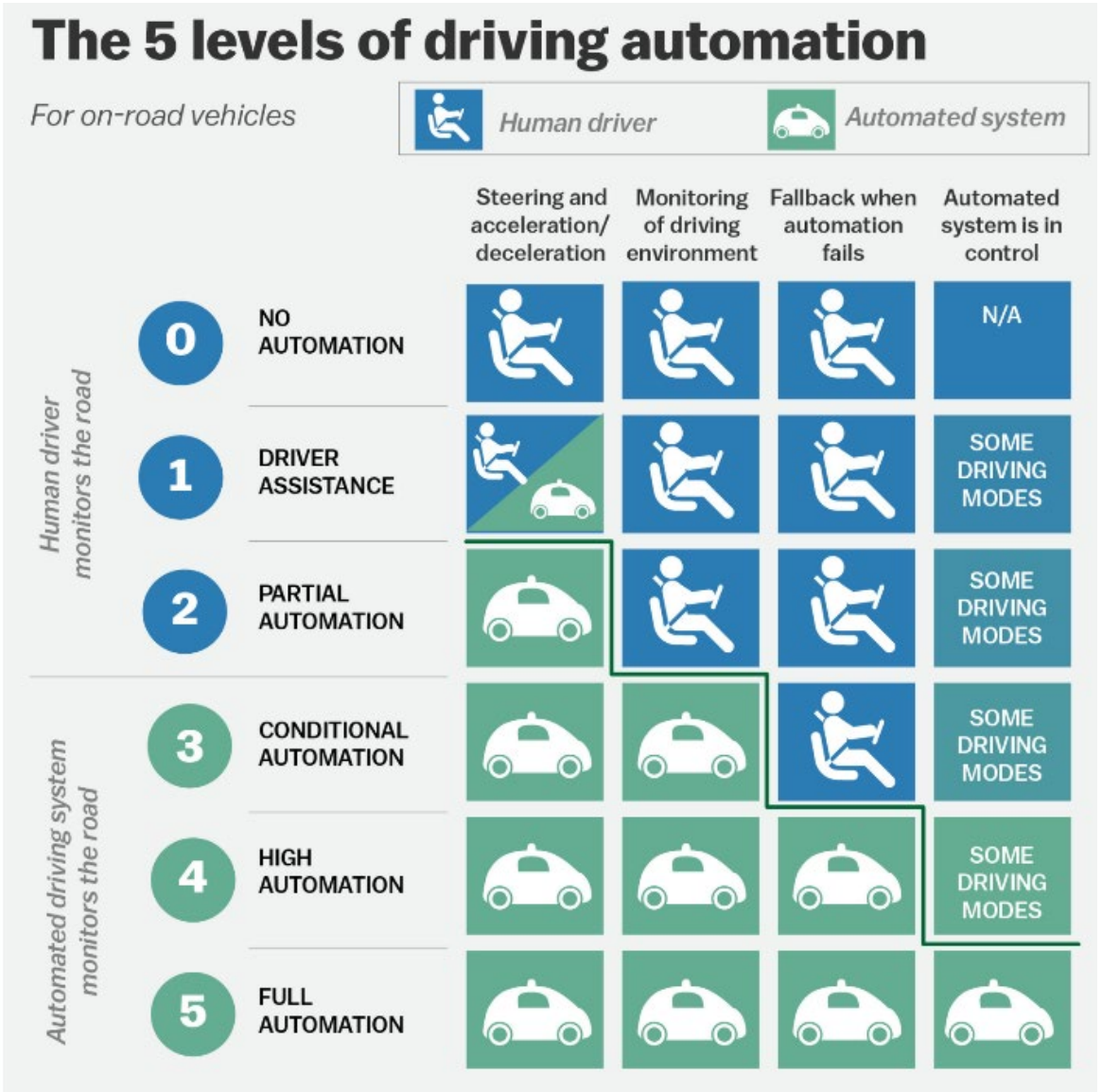
Connected and Automated Vehicle Realities

December 11, 2019



2016: 37,806
2017: 37,133
2018: 36,750

Source: Insurance Institute for Highway Safety & National Highway Traffic Safety Administration


The 5 levels of driving automation
For on-road vehicles
Human driver
Automated system
Steering and acceleration/ deceleration
Monitoring of driving environment
Fallback when automation fails
Automated system is in control
Human driver monitors the road
0
NO AUTOMATION
N/A
1
DRIVER ASSISTANCE
SOME DRIVING MODES
2
PARTIAL AUTOMATION
SOME DRIVING MODES
Automated driving system monitors the road
3
CONDITIONAL AUTOMATION
SOME DRIVING MODES
4
HIGH AUTOMATION
SOME DRIVING MODES
5
FULL AUTOMATION

Input Variables

- Level 4 Capabilities = 2019
- Level 4/5 Passenger Vehicles = 2023
- Level 4/5 Every New Passenger Vehicle = 2030
- Median Fleet Age = 11.5 years
- Fleet Turnover = 23 years

Equation

2030 + 23 = ……2053

Exhibit 11 **Vehicle Technology Deployment Summary**

Technology	Deployment Cycle	Typical Cost Premium	Market Saturation Share
Automatic transmissions	50 years (1940s-90s)	$1,500	90% U.S., 50% worldwide
Air bags	25 years (1973-98)	A few hundred dollars	100%, due to federal mandate
Hybrid vehicles	25+ years (1990s-2015+)	$5,000	Uncertain. Currently about 4%.
Subscription services	15 years	$250 annual	2-5%
Navigation systems	30+ years (1985-2015+)	$500 and rapidly declining	Uncertain; probably over 80%.

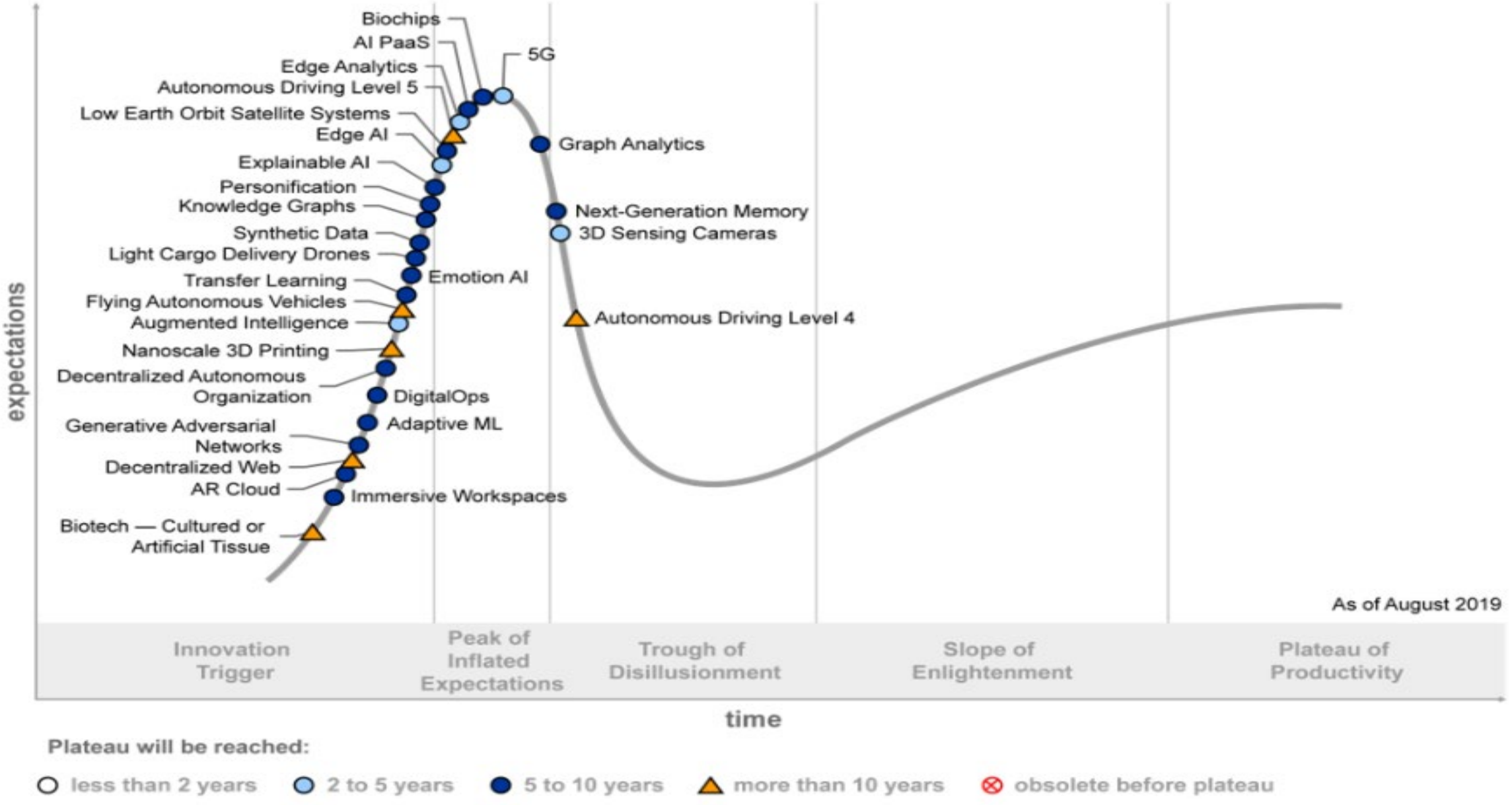
New technologies usually require several decades between commercial availability to market saturation.

Exhibit 13 **Autonomous Vehicle Market Penetration Projections**

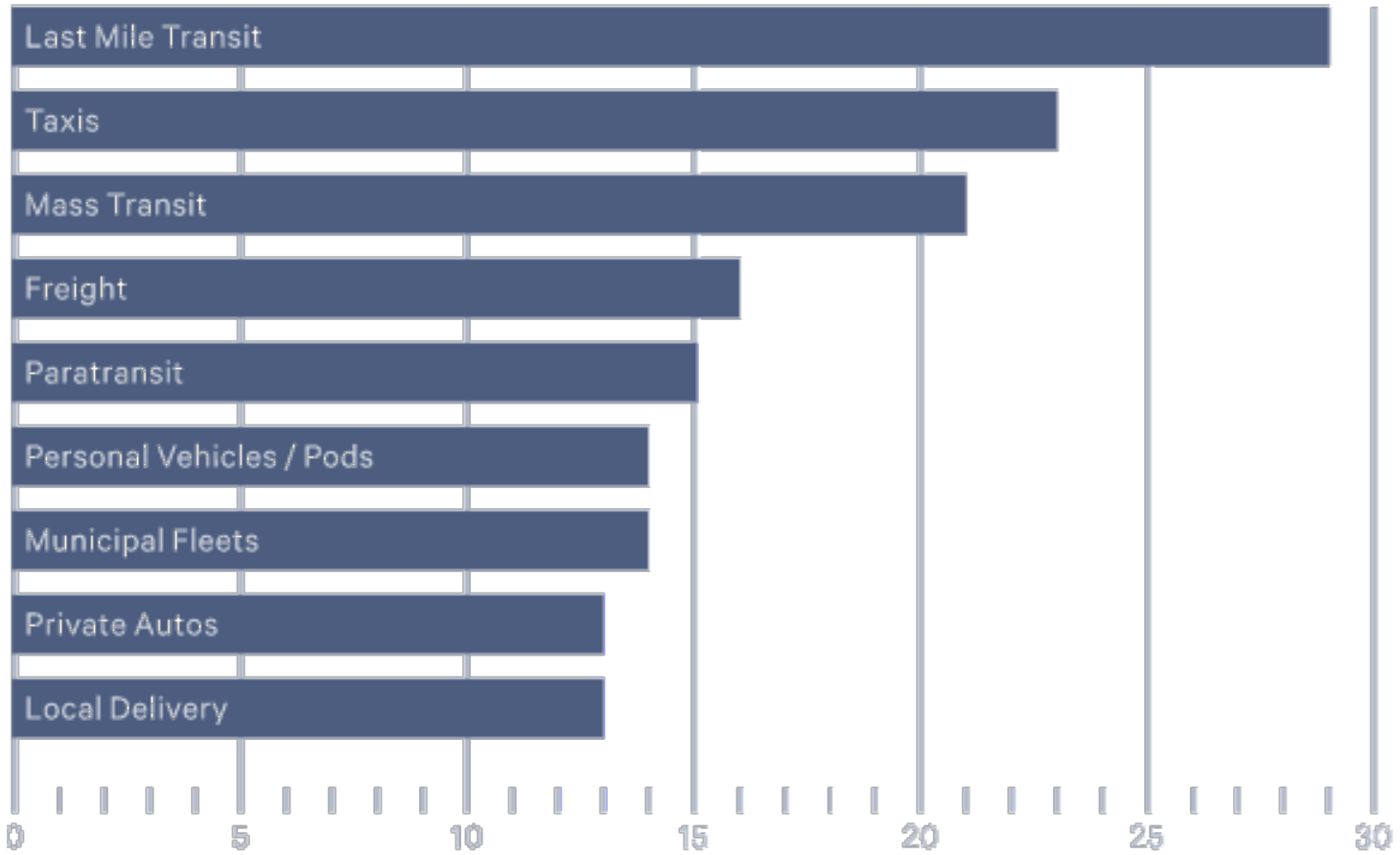
Stage	Decade	New Sales	Fleet	Travel
Available with large price premium	2020s	2-5%	1-2%	1-4%
Available with moderate price premium	2030s	20-40%	10-20%	10-30%
Available with minimal price premium	2040s	40-60%	20-40%	30-50%
Standard feature included on most new vehicles	2050s	80-100%	40-60%	50-80%
Saturation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

Autonomous vehicle will probably take several decades to penetrate new vehicle sales, fleets and total vehicle travel.

Source: Victoria Transport Policy Institute

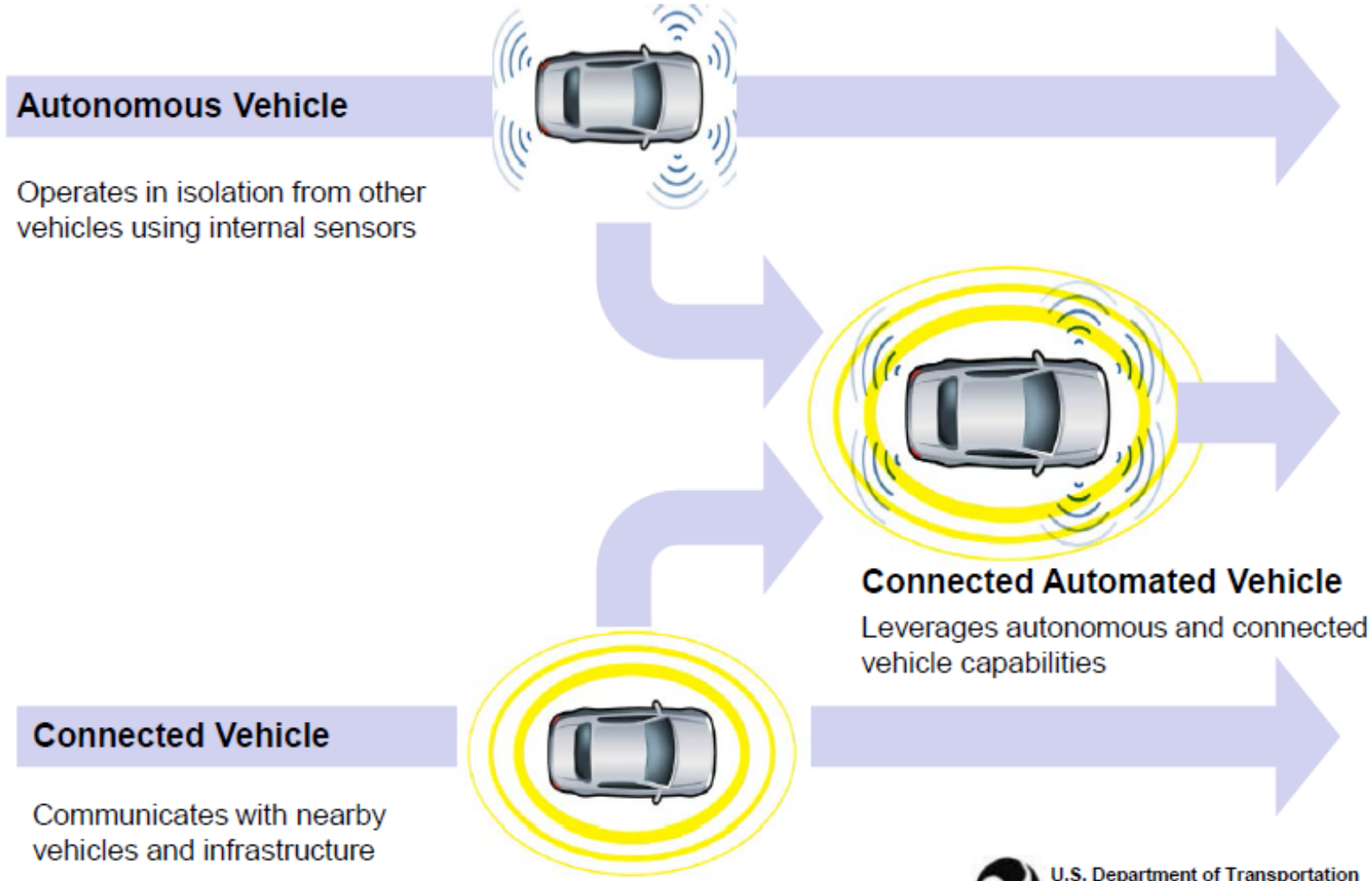

Biochips
AI PaaS
Edge Analytics
Autonomous Driving Level 5
Low Earth Orbit Satellite Systems
Edge AI
Explainable AI
Personification
Knowledge Graphs
Synthetic Data
Light Cargo Delivery Drones
Transfer Learning
Flying Autonomous Vehicles
Augmented Intelligence
Nanoscale 3D Printing
Decentralized Autonomous Organization
Generative Adversarial Networks
Decentralized Web
AR Cloud
Biotech — Cultured or Artificial Tissue
5G
Graph Analytics
Next-Generation Memory
3D Sensing Cameras
Emotion AI
Autonomous Driving Level 4
DigitalOps
Adaptive ML
Immersive Workspaces
expectations
As of August 2019
Innovation Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
time
Plateau will be reached:
less than 2 years
2 to 5 years
5 to 10 years
more than 10 years
obsolete before plateau

Anticipated AV Use Cases



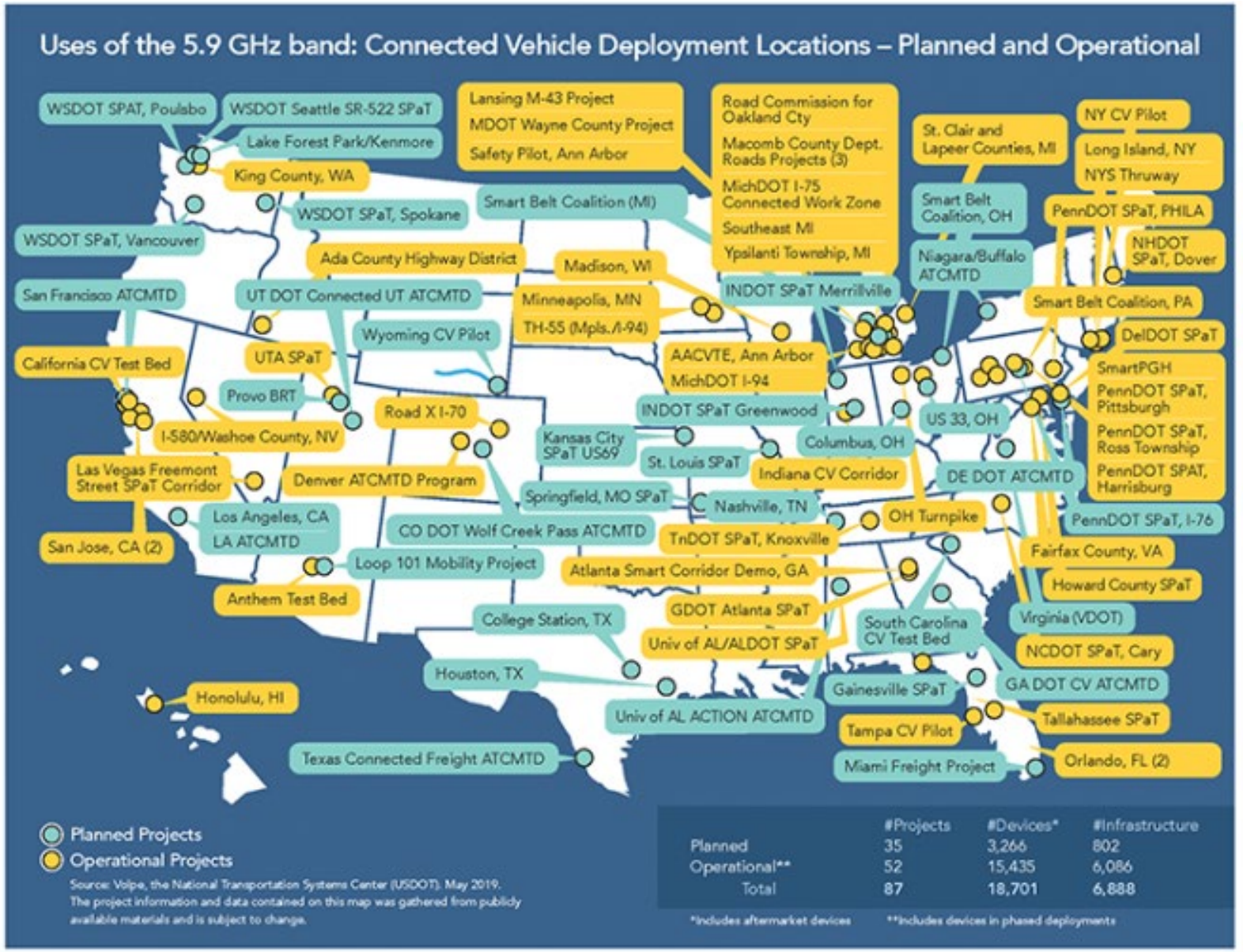
Source: Bloomberg.org

Connected Vehicles / Automated Vehicles



U.S. Department of Transportation
ITS Joint Program Office


ONLY



Source: USDOT

V2X Technology

Crash reduction and environmental improvement
while adhering to regulations in each region

TOYOTA supports interoperable, fully-validated and government-supported V2X technologies.

V2X Short Range Environment

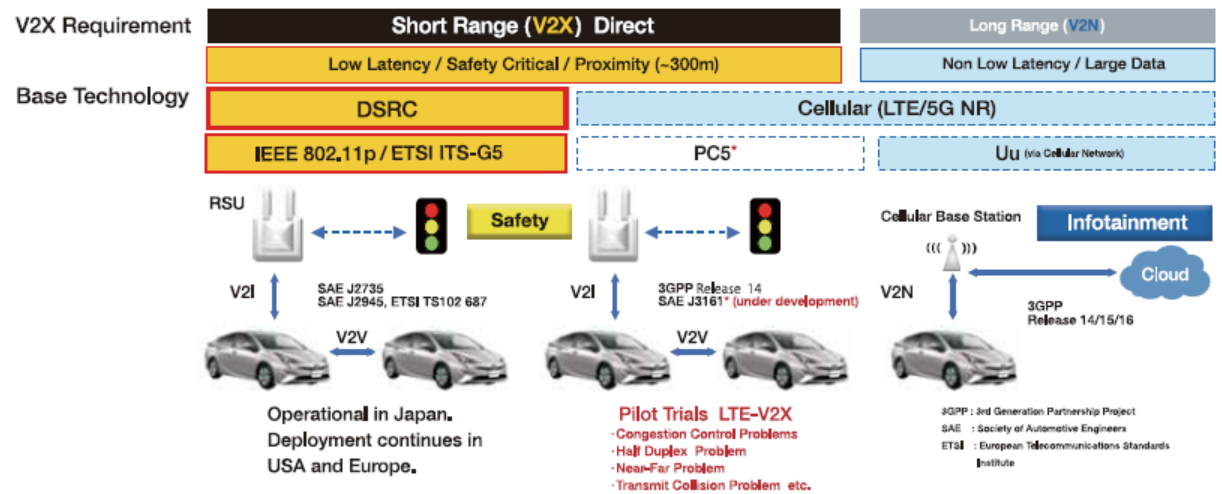
Estimation by TOYOTA

	Japan	USA	Europe	China	Australia
V2X Technology	DSRC (ITS Connect)	DSRC	DSRC (ITS-G5)	LTE-V2X	DSRC / LTE-V2X
Frequency	760 MHz 755-765 MHz	5.9 GHz 5,850-5,925 GHz	5.9 GHz 5,855-5,925 GHz	5.9 GHz 5,905-5,925 GHz	5.9 GHz 5,855-5,925 GHz
Deployment Status	Commercial	Operational	Announcement	Pilot	Proof of Concept

V2X Hybrid Communication

Using both DSRC and Cellular Appropriately

Vehicle-to-everything (V2X) connectivity is achieved with a combination of Short-range direct communication (DSRC for Safety) and Long-range network communication (Cellular-V2N) – "Hybrid Communication".



TOYOTA

Technology and Travel Behavior

How Transportation Technology Could Impact Travel Demand

Induced Mobility ↑ | ZOV Trips ↑ | Longer Commutes ↑↓





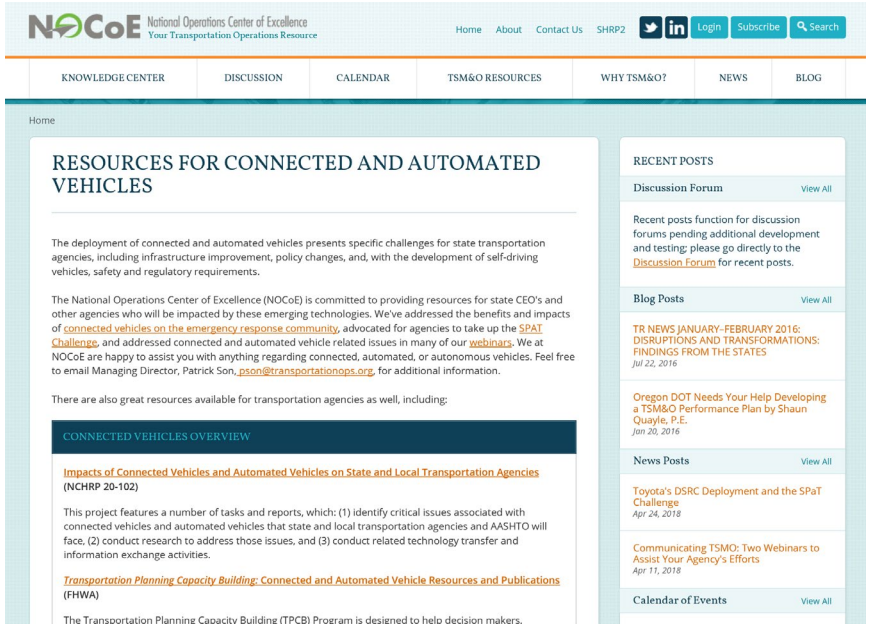

Induced Mobility ↑ | Short Trips ↑ | Parking ↓

Challenges/Opportunities for Public Agencies

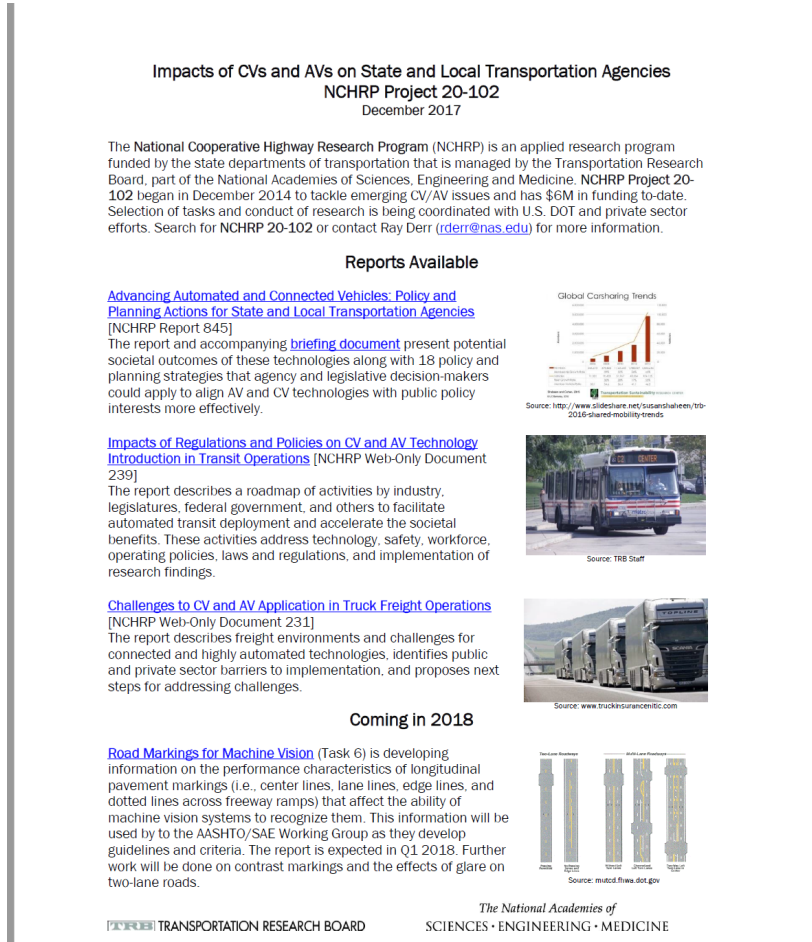
- Vehicles
- Signal System Upgrades
- Infrastructure Improvements
- Communications Networks
- Data Management
- Workforce Development
- Business Processes
- Cybersecurity
- Partnering
- Technology Advancement
- Regulatory Developments
- Financing/Business Models

Photo: psu.edu

Resources



NCHRP 20-102



Impacts of CVs and AVs on State and Local Transportation Agencies
NCHRP Project 20-102
December 2017

The National Cooperative Highway Research Program (NCHRP) is an applied research program funded by the state departments of transportation that is managed by the Transportation Research Board, part of the National Academies of Sciences, Engineering and Medicine. NCHRP Project 20-102 began in December 2014 to tackle emerging CV/AV issues and has $6M in funding to-date. Selection of tasks and conduct of research is being coordinated with U.S. DOT and private sector efforts. Search for NCHRP 20-102 or contact Ray Derr (rderr@nas.edu) for more information.

Reports Available

Advancing Automated and Connected Vehicles: Policy and Planning Actions for State and Local Transportation Agencies [NCHRP Report 845]
The report and accompanying briefing document present potential societal outcomes of these technologies along with 18 policy and planning strategies that agency and legislative decision-makers could apply to align AV and CV technologies with public policy interests more effectively.

Global Carsharing Trends
Source: http://www.slideshare.net/susanshaheen/trb-2016-shared-mobility-trends

Impacts of Regulations and Policies on CV and AV Technology Introduction in Transit Operations [NCHRP Web-Only Document 239]
The report describes a roadmap of activities by industry, legislatures, federal government, and others to facilitate automated transit deployment and accelerate the societal benefits. These activities address technology, safety, workforce, operating policies, laws and regulations, and implementation of research findings.

Source: TRB Staff

Challenges to CV and AV Application in Truck Freight Operations [NCHRP Web-Only Document 231]
The report describes freight environments and challenges for connected and highly automated technologies, identifies public and private sector barriers to implementation, and proposes next steps for addressing challenges.

Source: www.truckinsurancenitic.com

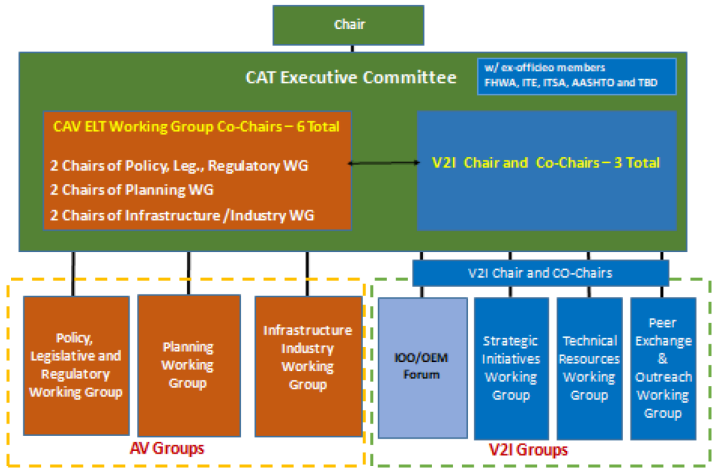
Coming in 2018

Road Markings for Machine Vision (Task 6) is developing information on the performance characteristics of longitudinal pavement markings (i.e., center lines, lane lines, edge lines, and dotted lines across freeway ramps) that affect the ability of machine vision systems to recognize them. This information will be used by to the AASHTO/SAE Working Group as they develop guidelines and criteria. The report is expected in Q1 2018. Further work will be done on contrast markings and the effects of glare on two-lane roads.

Source: mutcd.fhwa.dot.gov

TRB TRANSPORTATION RESEARCH BOARD
The National Academies of SCIENCES · ENGINEERING · MEDICINE

Cooperative Automated Transportation (CAT) Coalition



Thank you!

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