



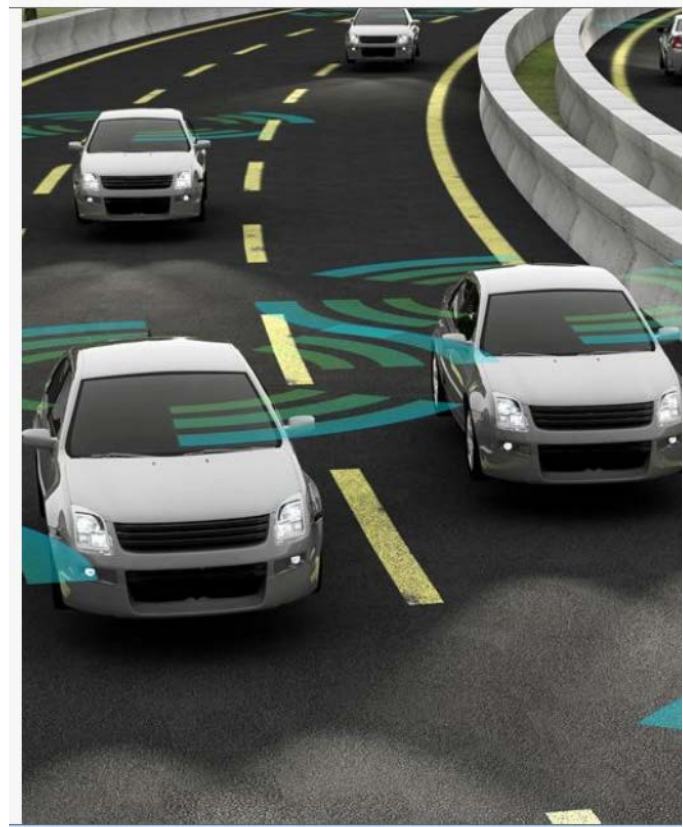
Connected and Automated Vehicles

Jay Hietpas, P.E.

Connected and Automated Vehicles Director

Presentation Overview

- Connected and Automated (CAV) Background
- CAV Activities in Minnesota



Connected Automation

Autonomous Vehicles

Operates in isolation from other vehicles using sensors



Connected Vehicles

Communicates with vehicles and infrastructure



Connected Automated Vehicle
Uses connected and automated technologies





0

1

2

3

4

5

No
Automation

Driver
Assist

Partial
Automation

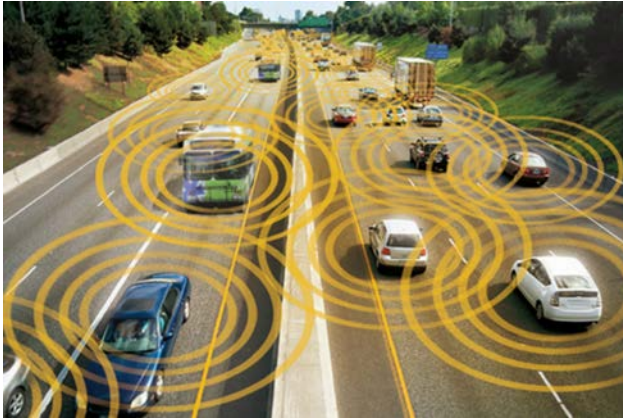
Conditional
Automation

High
Automation

Full
Automation

Society of Automotive Engineers (SAE) Levels of Automation

Items Being Considered

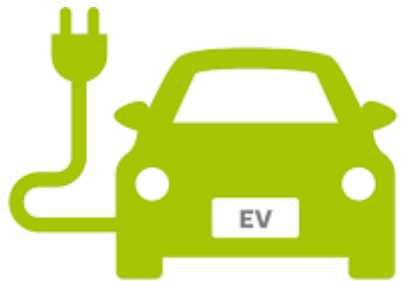


Automated & Connected Vehicles



Truck Platooning

Automated Delivery Services



Electric Vehicles



Mobility as a Service
(MAAS)



CAV - When Will It Come?

GM will make an autonomous car without steering wheel or pedals by 2019 87

'Platoons' of autonomous trucks will drive

Consumer Availability and Market Penetration Rates

?????

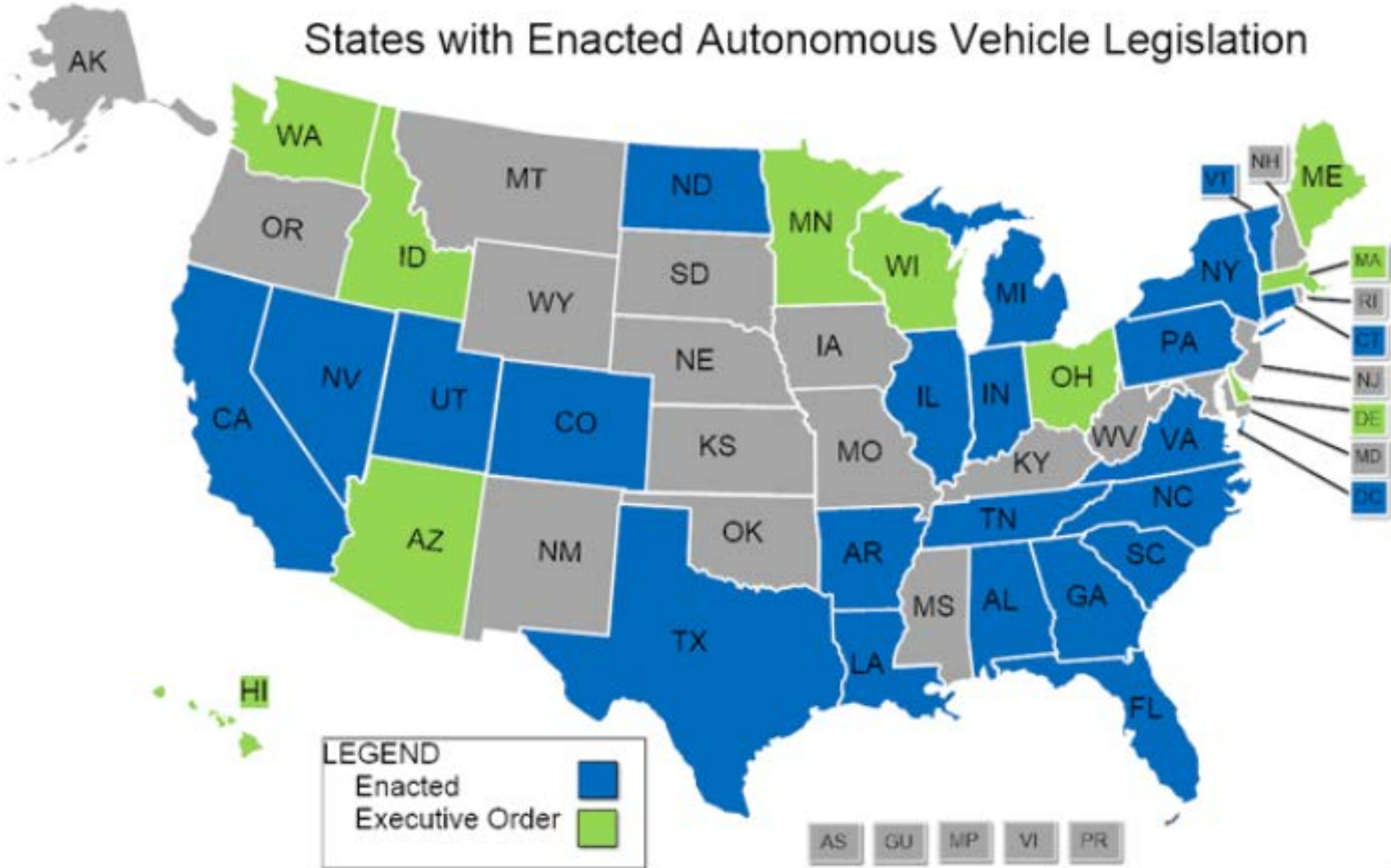
to buy up to autonomous vehicles from Volvo

Toyota to introduce DSRC-based connected vehicles in the USA from 2021

Pieces of Automation Already Available

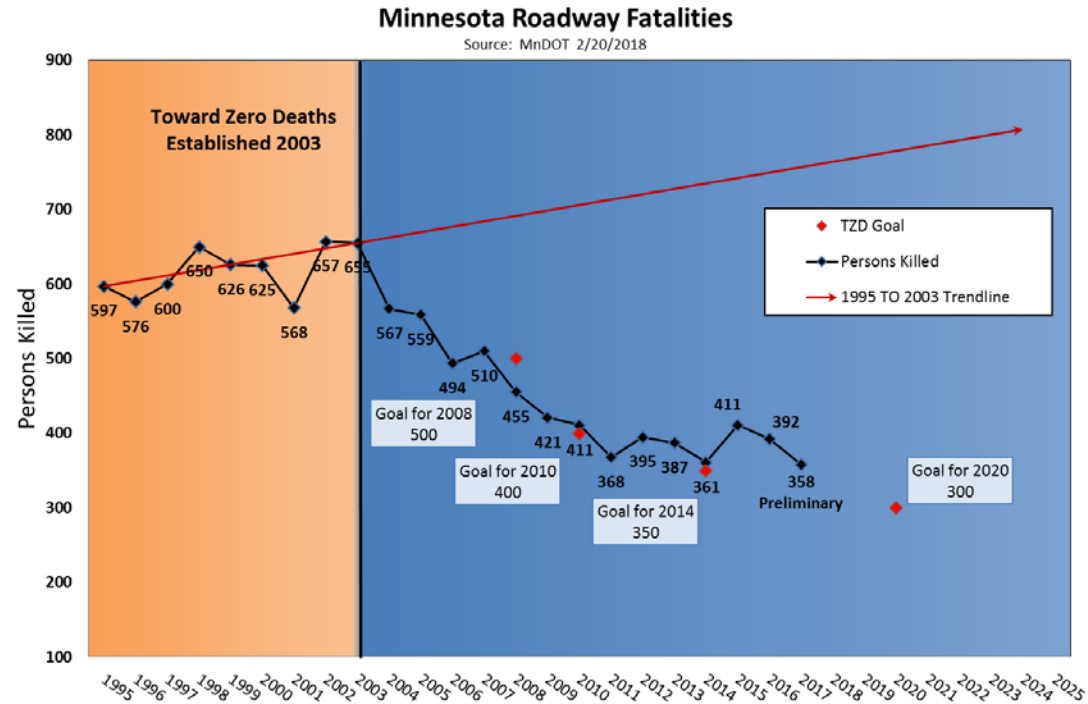
- Adaptive Cruise Control
- Self Parking Features
- Lane Departure Systems
- GM Super Cruise / Tesla Auto-Pilot
- V2I – Signal Systems (Audi, BMW, Apps)
- Self Driving Tests

National Items



What is the Impact to Minnesota?

- Safety
- Changes in operations
- Infrastructure Changes
- Regulation
- Mobility Opportunities
- Business Opportunities



What are the Challenges?



Snow / Ice

Salt



Other Impacts

Parking Impacts

Freight

Cyber Security

Pavement Markings

Geometric

Licensing Laws

Bridge Loads

Design

Smart Signs

Pavement Impacts

Traffic Operations

Revenue

Mixed Traffic (AV & Non-AV)

Staffing

Land Use / Planning

Activities in Minnesota

- CAV-X Office
 - Policy
 - Research & Implementation Funding
- CTS Automated Vehicle Visioning Workshop
- Executive Order 18-04
- MnDOT CAV Strategic Plan
- Autonomous Shuttle Testing
- Connected Corridors Project



Executive Order – Expected Outcomes

Advisory Council

- Study, assess, and prepare for the transformation and opportunities associated CAVs
- Develop recommendations for changes in state law
- Submit Report to Legislature by December 1, 2018.
- Establish programs for development, testing, and deployment;

Minnesota Connected and Automated Vehicles EO Organization Structure

Advisory Council

I-CAV Team

Transportation Infrastructure

Cyber security and data privacy standards

Vehicle Registration, Driving Training, Licensing

Insurance

Traffic Regulations

Economic Development, Business Opportunities, Workforce Development

Accessibility and Equity

Policy and Planning

Stakeholders

Stakeholders

Stakeholders

Stakeholders

Stakeholders

Stakeholders

Stakeholders

Stakeholders

MnDOT CAV Strategic Vision



Safe Automated Vehicle Testing Demonstration

Project Goals

Snow and Ice Testing

Identify Infrastructure

Identify Operations Impacts

Improve Future Mobility Options

Increase Minnesota's Influence

Develop Partnerships

Public Feedback



Downtown Minneapolis - Nicollet Mall Demo



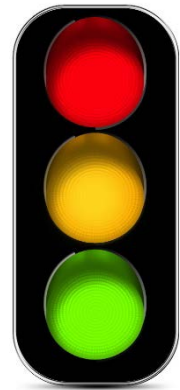
TOTAL riders for the 3 day demo: **1279**

Connected Vehicles Corridor



Connected Vehicle Applications

- 1: Signal Phase and Timing (SPaT)
- 2: Transit/Pedestrian Conflict Warning
- 3: Snow Plow Signal Priority
- 4: CV Data Exchange
- 5: Mobile Work Zone Warning System
- 6: Transit/MnPASS Lane Status Notification System



Thank you again!



Jay Hietpas, PE

CAV-X Director

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Transportation Advisory Board

May 16, 2018

Planning for Connected and Automated Vehicles

Planning

The nation, state, region and local governments are facing great opportunity with automated vehicle technologies, yet also great uncertainty as this new technology develops and is implemented across our various environments.

As yet, CAV has Uncertain Outcomes....

COULD DECREASE DUE TO	IMPLICATION	COULD INCREASE DUE TO
Vehicle sharing, higher vehicle costs	Vehicle Ownership	Smaller, lighter-weight vehicles lower cost, new types of vehicles
Increased travel willingness / better use of in-vehicle time	Land Use Density	Network effects, shared & transit vehicles, less parking
Vehicle sharing, denser development	VMT / Trips	Lower operating costs, zero-occupant trips, mode shift, expanded mobility for non-drivers, increased travel willingness
Follows all road rules / defensive driving	Road Capacity / Speed	Reduced headways, smoother traffic flow, shorter signal lag times, fewer crashes, and real-time route optimization
Machine precision	Crashes	Hacking, complex human-machine interactions
Low-emission vehicles, right-sized vehicles, eco-driving	Air and Noise Pollution	More travel, larger vehicles
Vehicles avoid deficiencies, smoother traffic flow	Pavement Distress	Platooning / closer vehicle spacing, increased VMT
AI (deep learning) displaces workers	Jobs	Technology creates more new high-skill jobs than the lower-skill ones it disrupts

Source: DVRPC, 2017. Adapted from Bryant Walker Smith, *How Governments Can Promote Automated Driving*, *New Mexico Law Review*, forthcoming, March 17, 2016, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2749375; and Johanna Zmud, Ginger Goodin, Maarit Moran, Nidhi Kalra, and Eric Thorn, *Advancing Automated and Connected Vehicles: Policy and Planning Strategies for State and Local Transportation Agencies*, National Cooperative Highway Research Program; Transportation Research Board, National Academies of Sciences, Engineering, and Medicine, 2017, <http://nap.edu/24872>.

How will autonomous vehicles arrive?

Fully
Autonomous

Personal Automation



**Shared Automated/
Platooning**



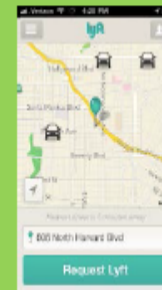
Semi-
Autonomous

Driver

Business as Usual



Shared Mobility



Personally Owned

Mobility Fleets

Agency Roles

Definition and understanding of various public agency roles is still evolving.....

- MnDOT
- Local governments
- University
- Transit operators
- Metro Council as the Metropolitan Planning Organization

Regional Outcomes and Goals

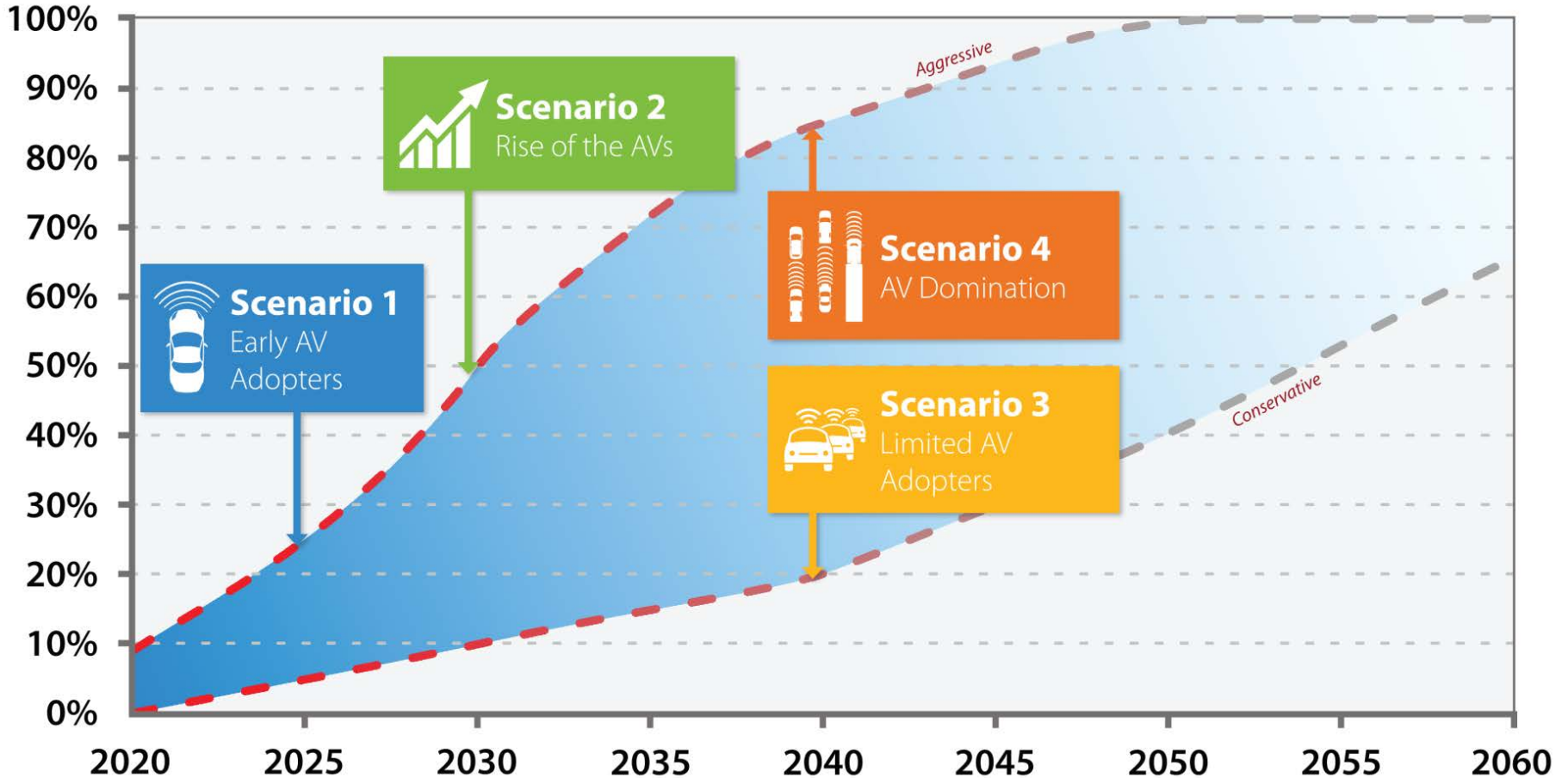
Successful implementation of CAV technology means positive impacts on the outcomes and goals identified by the region.....

- Thrive regional outcomes: Stewardship, Prosperity, Equity, Livability, and Sustainability
- Transportation goals: System Stewardship, Safety and Security, Access to Destinations, Competitive Economy, Healthy and Equitable Communities, Leveraging Transportation Investments to Guide Land Use

Council MPO Roles

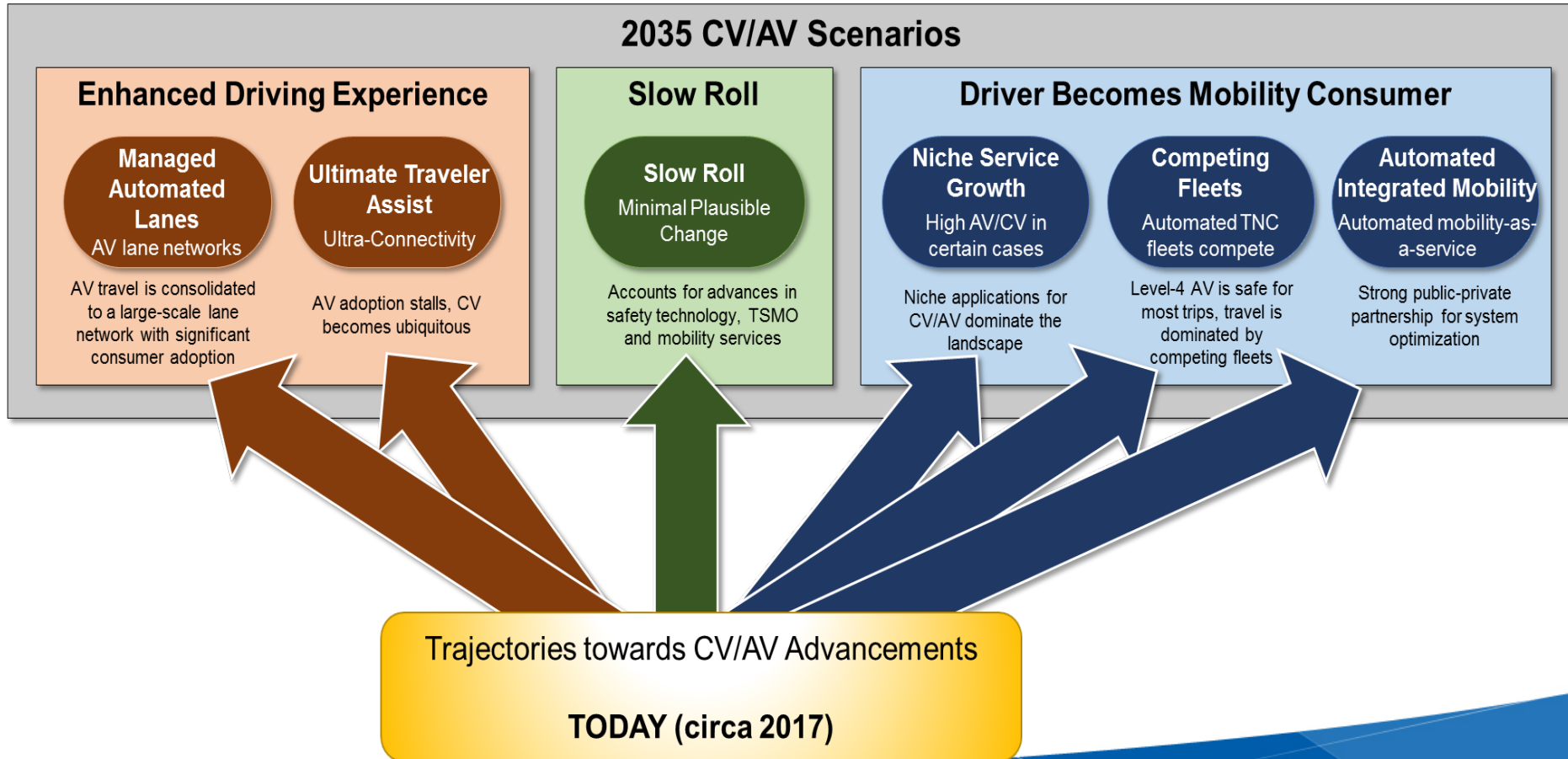
- Connect the development and deployment of CAV to regional outcomes and goals
- Provide a forum and process for policy-makers and the public to be involved
- Ensuring concerns of all modes and users are addressed
- Monitor national and state activities and trajectory of CAV adoption, share knowledge
- Scenario and performance based planning

Potential Penetration of AV



Source: Maricopa Association of Governments; HDR Engineering, Inc.

FHWA Scenario Planning



Council Focus Areas

MPO work efforts will focus on understanding the impacts of CAV on:

- Travel behavior
- Revenues
- Investment needs
- Equity
- Land use

Work Program Activities

- Participation in local and national activities
 - Governor's CAV Advisory Council
 - MnDOT CAV Strategic Plan
 - CTS CAV Workshop June 2018
 - AMPO Draft National Framework for Regional CAV Planning
 - FHWA CAV scenario modeling
- TPP Work Program
 - Regional framework and issues analysis
 - Scenario modeling and performance measurement
 - Integrating CAVs into the Congestion Management Process
 - Emerging truck technologies
 - Transportation investment needs assessment

2017 Work

Owned/Shared Scenario Modeling

- Modeled changes in highway system performance at various levels of CAV deployment and combinations of owned versus shared CAVs
- Outcomes examined:
 - Vehicle miles traveled (VMT) and congested VMT
 - Average speeds
 - Number and % of unoccupied vehicle trips
 - % VMT occurring in unoccupied vehicles

2017 CAV Modeling Conclusions

- Number of vehicle trips and vehicle miles traveled increases substantially due to new unoccupied vehicle trips under both scenarios
- Number of congested miles increased substantially under both scenarios
- Worst case congestion scenario is during mixed fleet of CAV and non-CAV
- Number of vehicles in the region decreases under both owned and shared scenarios

Why Shared Autonomous Vehicles are Coming - Fast

Thomas Fisher

Professor and Director

Minnesota Design Center, University of Minnesota

The change will happen faster than you think



A big driver of this change: cost of driving

Despite high costs and fast depreciation, substantial utilization can make shared, high-tech "mobility vehicles" economically compelling

Today's car



Future mobility car



The "mobility vehicle" is based on a small sedan that costs \$25,000 and is completely replaced every three years with no residual value. It is shared and, therefore, driven 40,000 miles per year. The average NYC cab is driven an average of 70,000 miles per year.

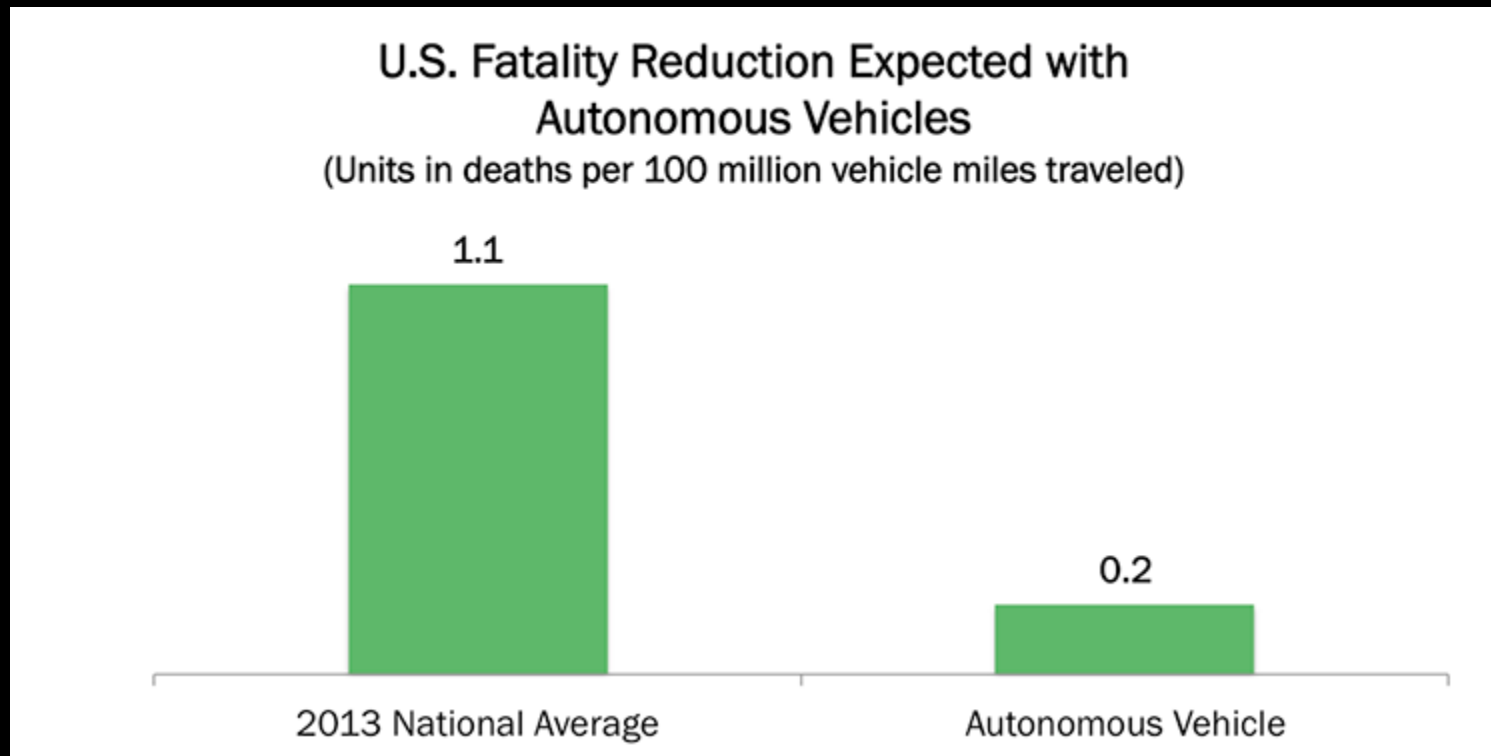
 **Fixed Costs (per mile)**
Depreciation, insurance, finance, and registration-related costs

 **Operating Costs (per mile)**
Gas, maintenance, and tires

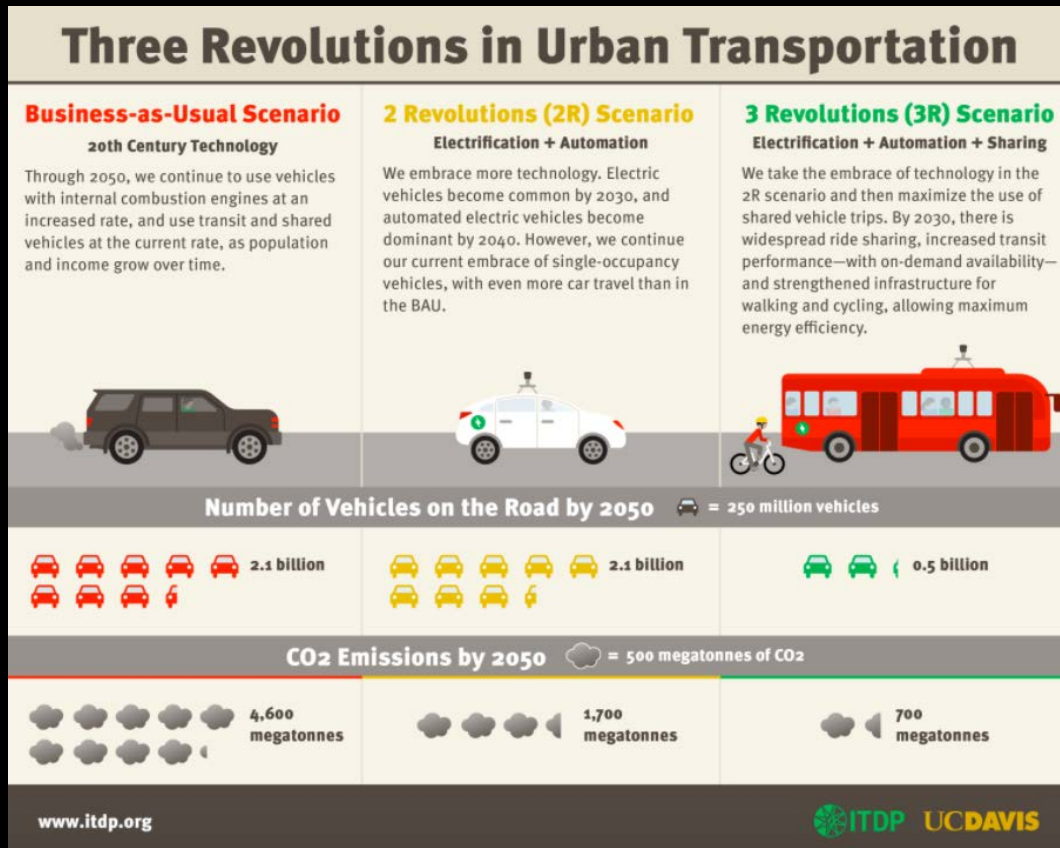
Sources: AAA, NYC Taxi and Limousine Commission, "KPMG LLP's Me, my vehicle, my life... in the ultra connected age"



A second driver: safety
















A third driver: reduced pollution



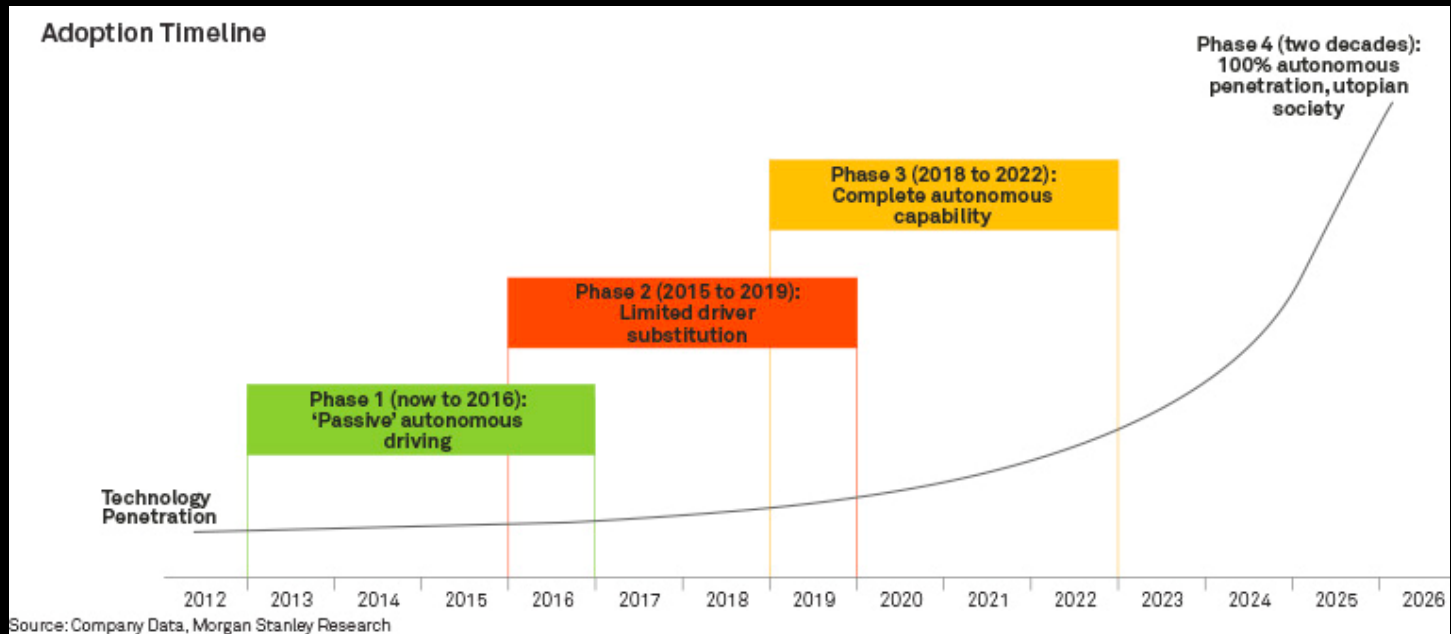
The big stick driving the change: insurance

Figure 2. Stakeholders and insurance products in the future of mobility

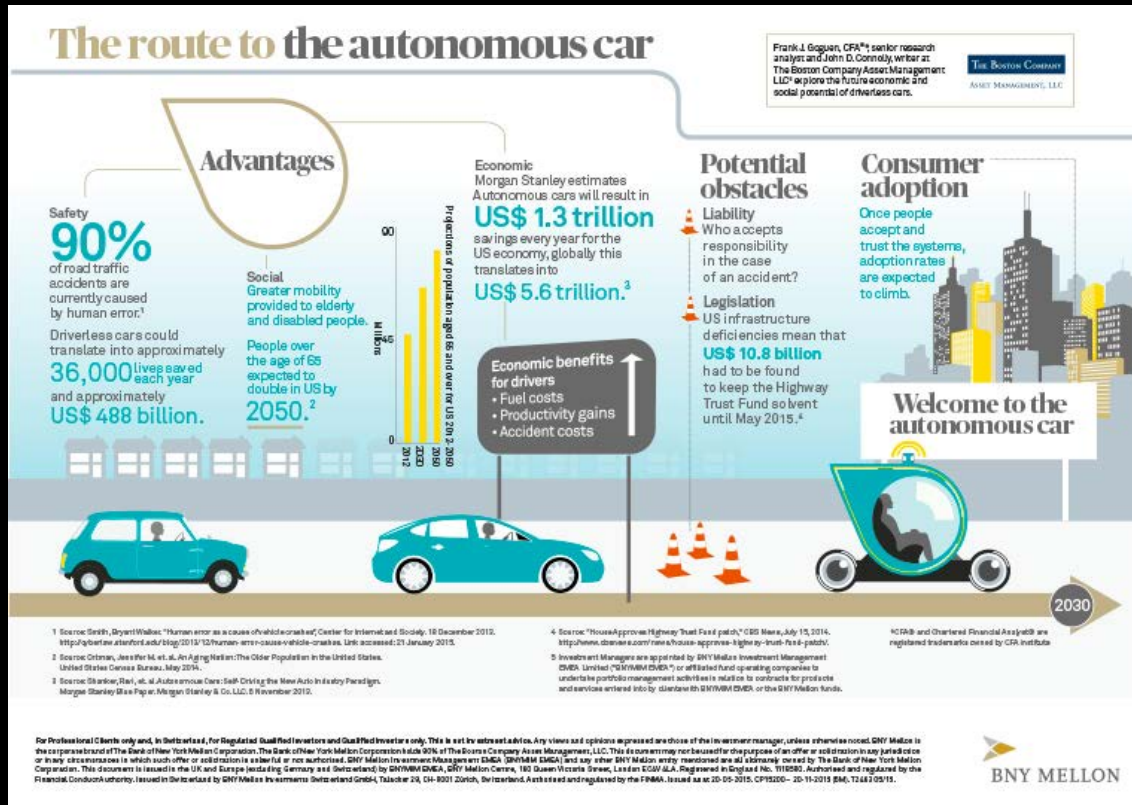
	Future state	Stakeholder model	Stakeholder	Primary coverages
Driver-driven	 1 Personally owned driver-driven	Traditional personal auto insurance	 Vehicle owner (individual)	Driver liability, collision, comprehensive
	 2 Shared driver-driven	Fleet (e.g., yellow cab, limo)	 Vehicle owner (commercial)	Driver liability, collision, comprehensive
		Owner/operator (e.g., black car)	 Vehicle owner (individual)	Driver liability, collision, comprehensive
		Rental	 Vehicle owner (commercial)	Comprehensive, liability (e.g., road worthiness)
		 Vehicle driver (individual)	Driver liability, collision	
Autonomous	 3 Personally owned autonomous	Personal autonomous vehicle insurance	 Vehicle owner (individual)	Comprehensive, liability (e.g., road worthiness)
	 4 Shared autonomous	Commercial autonomous vehicle insurance	 Vehicle owner (commercial)	Comprehensive, liability (e.g., road worthiness)
			 AV system manufacturer/ OS provider (commercial)	AV product liability
			 AV system manufacturer/ OS provider (commercial)	AV product liability

Graphic: Deloitte University Press | DUPress.com

Today's infrastructure will go through this change



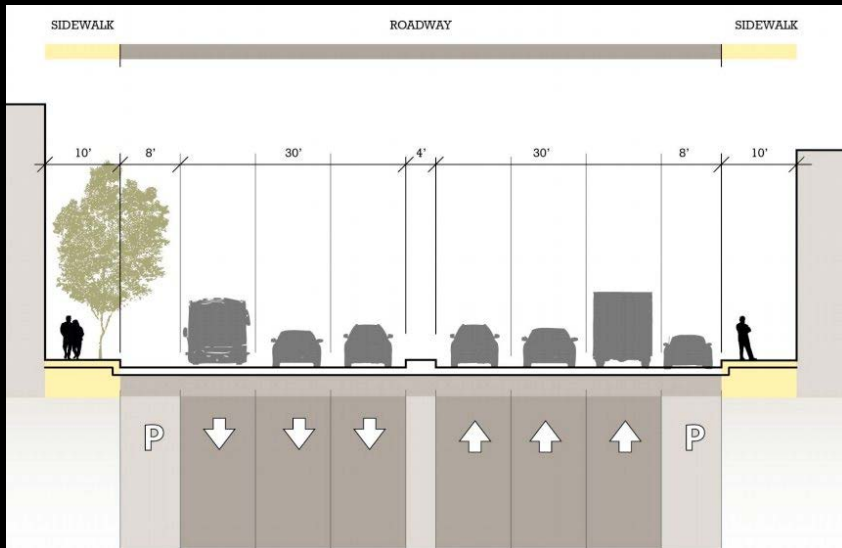
Opportunities and Challenges



This reflects a larger value shift : sharing economy



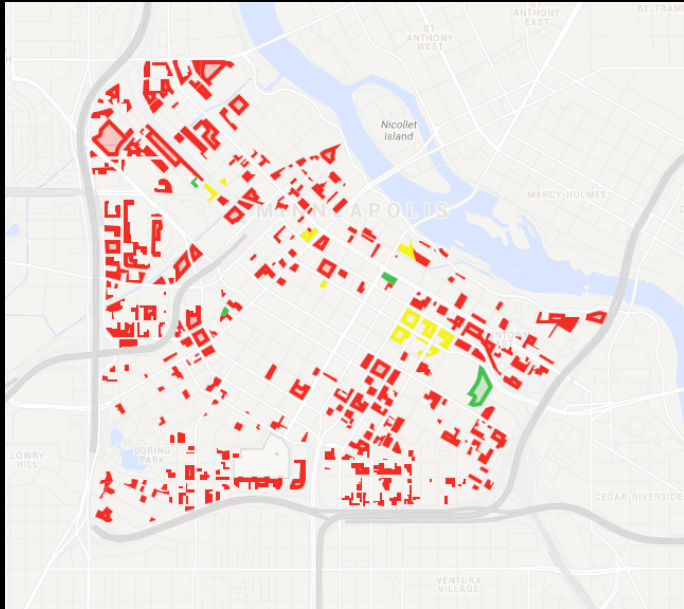
Public rights of way will feel the change first



Creating a lot more space for other things



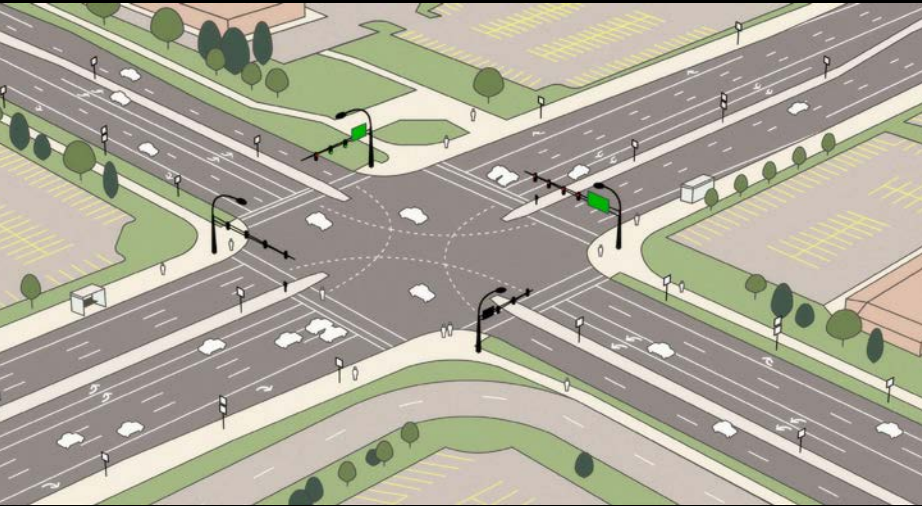
Cities will gain about 30% more land



Homeowners will gain land and interior space



The suburban landscape will change the most



Parking ramps will have to find other uses

CONVENTIONAL GARAGE DESIGNED TO ADAPT TO AUTONOMOUS VEHICLES

PHASE 1: 2018 - 2025

Today, the typical car is used only 5% of the time.
95% of the time it is parked: in a garage, at a house or on the street.

However, by the time today's garages are built, self parking cars and shared fleets will be a reality.



- 1 **TUCK AWAY DRIVERLESS CARS**
Driverless vehicle storage is packed in hyper-efficient rows on the top levels. Garages designed for self parking or autonomous vehicles can potentially improve their efficiency and use.
- 2 **INCREASE FLOOR TO FLOOR**
Floor to floor heights are designed to accommodate future uses such as residential or office.
- 3 **HARVEST TRAFFIC ENERGY**
Energy harvesting speed bumps recapture energy from passing vehicles.
- 4 **WALK UP PARKING ONLY ON LOWER LEVELS**
Conventional parking is kept off lower levels for increased accessibility.
- 5 **ARCHITECTURAL SKIN AS INTERACTIVE SURFACE**
Facade skin becomes a platform for personal virtual reality habitats as augmented projections replace horizontal screens.

By 2025, fully autonomous cars are expected to be available to the general public for an additional \$10,000. Source: Boston Consulting Group.

AUTONOMOUS VEHICLES & THE EVOLUTION OF THE PARKING GARAGE

PHASE 2: 2025 - 2035

As car ownership evolves to a subscription service with intelligent fleets, there will be less need for parking. Garages are transformed into other uses such as office, residential and hotels.

In 2035, the need for parking should decline by more than 5.7 billion square meters in the United States
(This equates to half the size of Connecticut). Source: McKinsey & Co.



- 1 **GARAGES EVOLVE...**
into residential, office, recreation and entertainment spaces.
- 2 **DRONE PACKAGE DELIVERY**
Ultra delivery vehicles land on the roof, building facade to access packages.
- 3 **CHARGING FLOOR**
Vehicles automatically charge when not being driven.
- 4 **VEHICLE RETRIEVAL ZONES**
Users call cars via personal mobile devices.

Highways will become multi-modal

