



Scenario Planning for Connected and Automated Vehicles

Association of Metropolitan Planning Organizations

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Process Step

Outputs for your Agency

1. Define and Understand CV/AV:

- Definitions and terminology surrounding CV and AV
- Knowledge of interrelated technologies and emergent phenomenon

2. Determine goals and stakeholders in your planning process

- Identifying agency goals from scenario planning
- Determining staff roles, task forces, and the scope of stakeholder outreach that is helpful and feasible for your agency's planning process
- Form a CV/AV scenario planning task force

3. Understand Driving Forces and Scenario Origins

- Ability to see how combinations of forces result in scenarios
- Understanding of the scenario development process
- Understanding of scenario ranking systems

4. Frame and Tailor the Scenarios

- Learn the fundamentals of the 6 CV/AV scenarios
- Tailor the scenarios to your region, identifying how they manifest locally
- Identify relevant regional stakeholders in each scenario

5. Incorporate Scenario Results into Decision-Making

- *Identify local risks and opportunities*
- *Create an action list and prioritize*
- *Adjust plans, policies, operational strategies, and investments*

6. Monitor industry and policy developments

- Monitor industry and policy developments related to CV and AV, and adjust plans where necessary



1. Define and Understand CV/AV:

- Definitions and terminology surrounding CV and AV
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Connected Vehicles

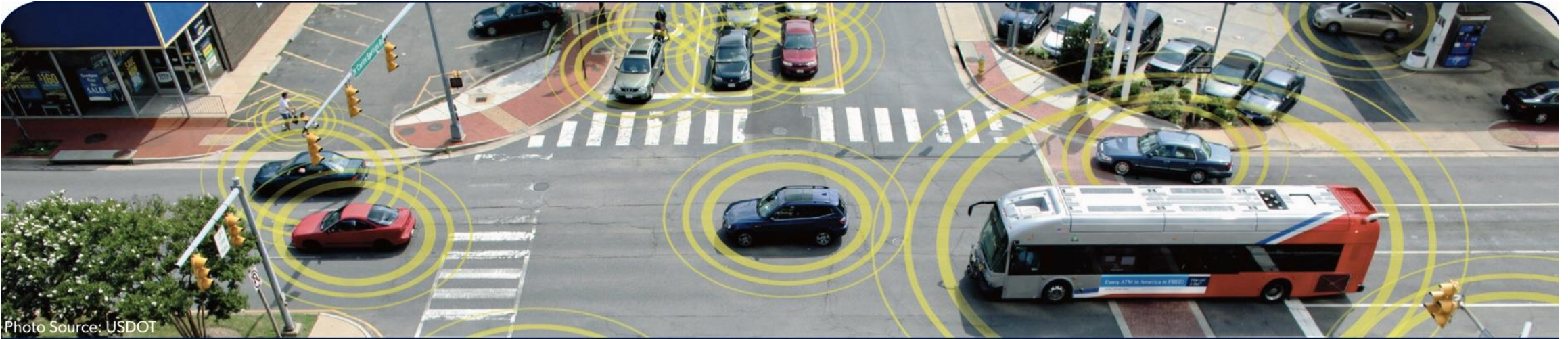


Photo Source: USDOT

Source: *CV Fact Sheet*. USDOT Intelligent Transportation Systems Joint Program Office 2015.

- Cars, trucks, buses “talk” to each other using wireless and/ or Dedicated Short Range Communications (DSRC) technology (V2V)
- Vehicles “talk” to roadway infrastructure traffic signals, toll booths, work zones, school zones, etc. (V2I)
- Vehicle systems alert drivers to real-time changes, threats, dangers, opportunities (V2X)

Autonomous Vehicles

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

Full Automation



0

No Automation

Zero autonomy; the driver performs all driving tasks.

1

Driver Assistance

Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.

2

Partial Automation

Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.

3

Conditional Automation

Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.

4

High Automation

The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.

5

Full Automation

The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Autonomous Vehicles

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**Driver
Assistance**



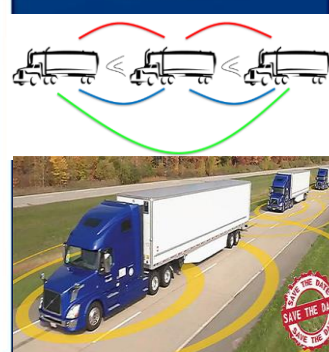
2

**Partial
Automation**



3

**Conditional
Automation**



4

**High
Automation**

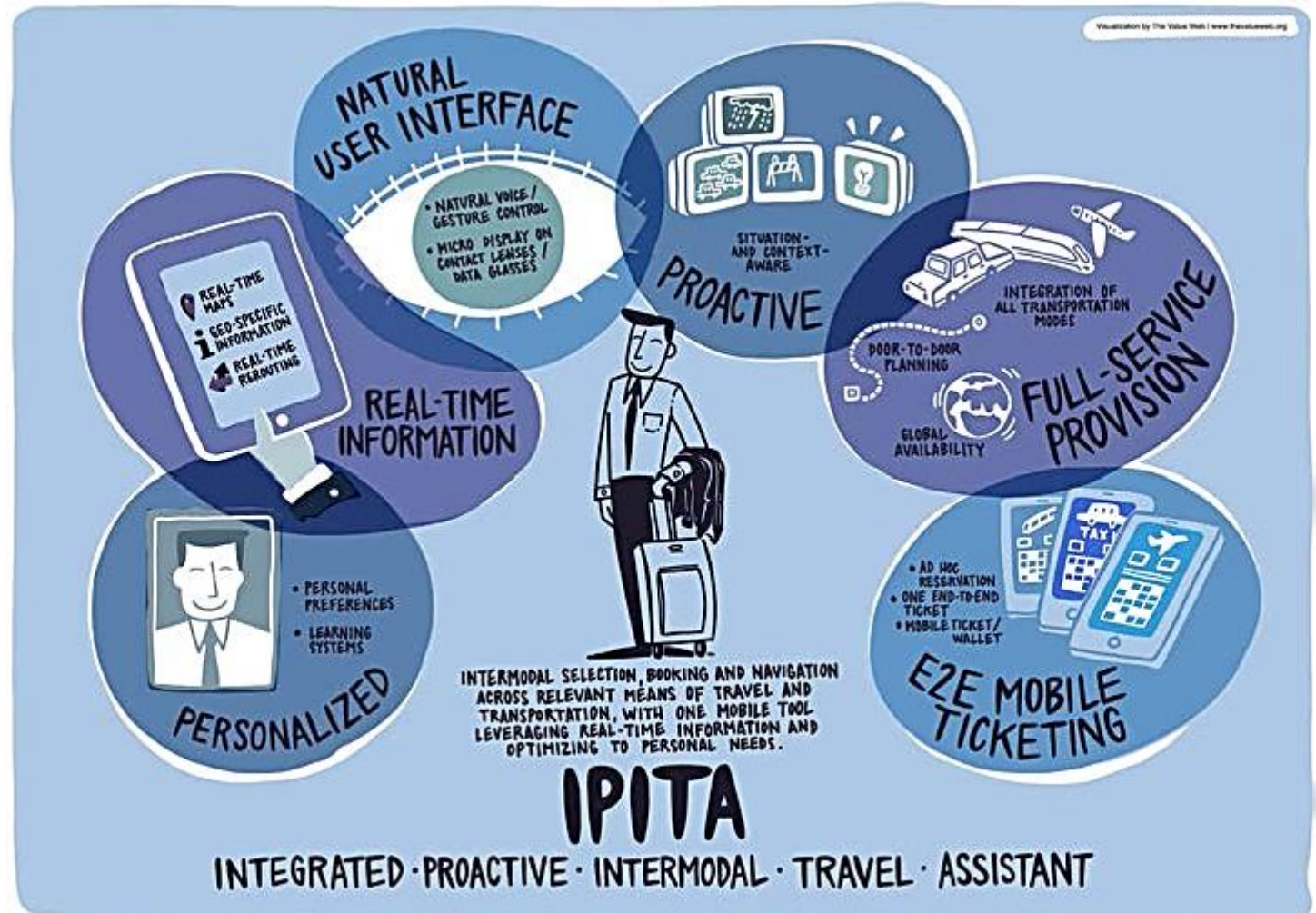


5


**Full
Automation**

Mobility as a Service

- Journey planning
- Shared cars, bikes, scooters
- Cross platform payment
- Subscriptions
- Transportation Network Companies (TNCs)
 - San Francisco, 2016: 20% of intra-city VMT (SFCTA)
 - US, 2030: 95% of US passenger miles (ReThinkX)
 - Platform for EV growth



Connected World, Hyperconnected Travel and Transportation in Action. World Economic Forum/ Boston Consulting Group. 2014. www3.weforum.org/docs/WEF_Connected_World_HyperconnectedTravelAndTransportationInAction_2014.pdf

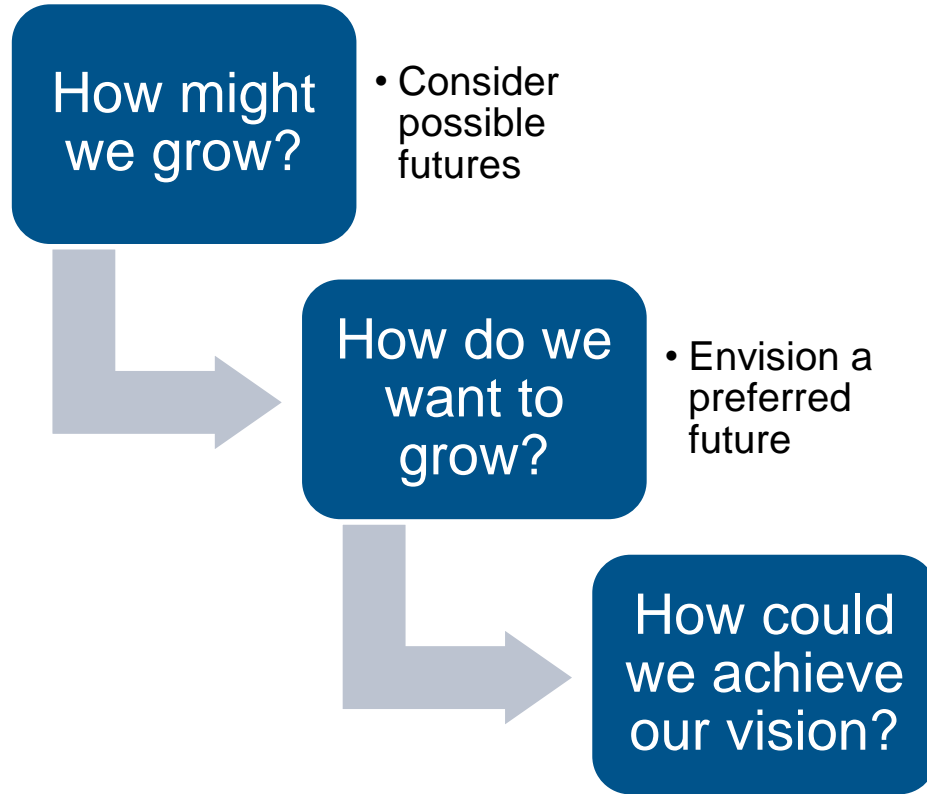


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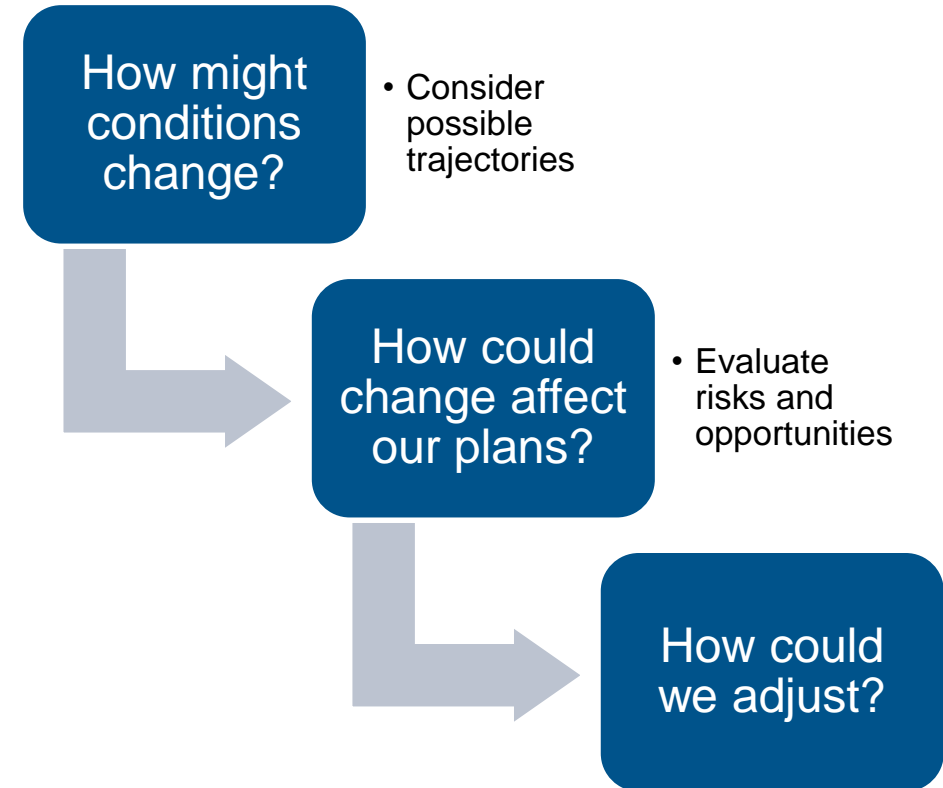
Types of Scenario Planning

Normative: What SHOULD happen?



Set Goals

Exploratory: What COULD happen?



Shape Tactics

What do you want to achieve?

- **What kinds of decisions will this support?**

- Long range plan goals, strategies, considerations
- Risk management
- Technology strategic plan
- Investments in emerging technology
- Investments affected by emerging technology
- Staff expertise and capacity

- **Who should be involved?**


- Technology / data experts
- Modeling staff
- Partners – transit agencies, private providers, universities....



Assemble Information/ Resources

- Transit availability/ ridership
- Demographic data/ forecasts
- Commuter mode share
- VMT/ congestion trends
- Current technology status
- Existing/ planned policies





3. Understand Driving Forces and Scenario Origins

- Ability to see how combinations of forces result in scenarios
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Scenario Building Blocks



Forces

environment... economy...
society... technology...



Levers

Investments in
infrastructure conditions...
travel choices... equitable
access

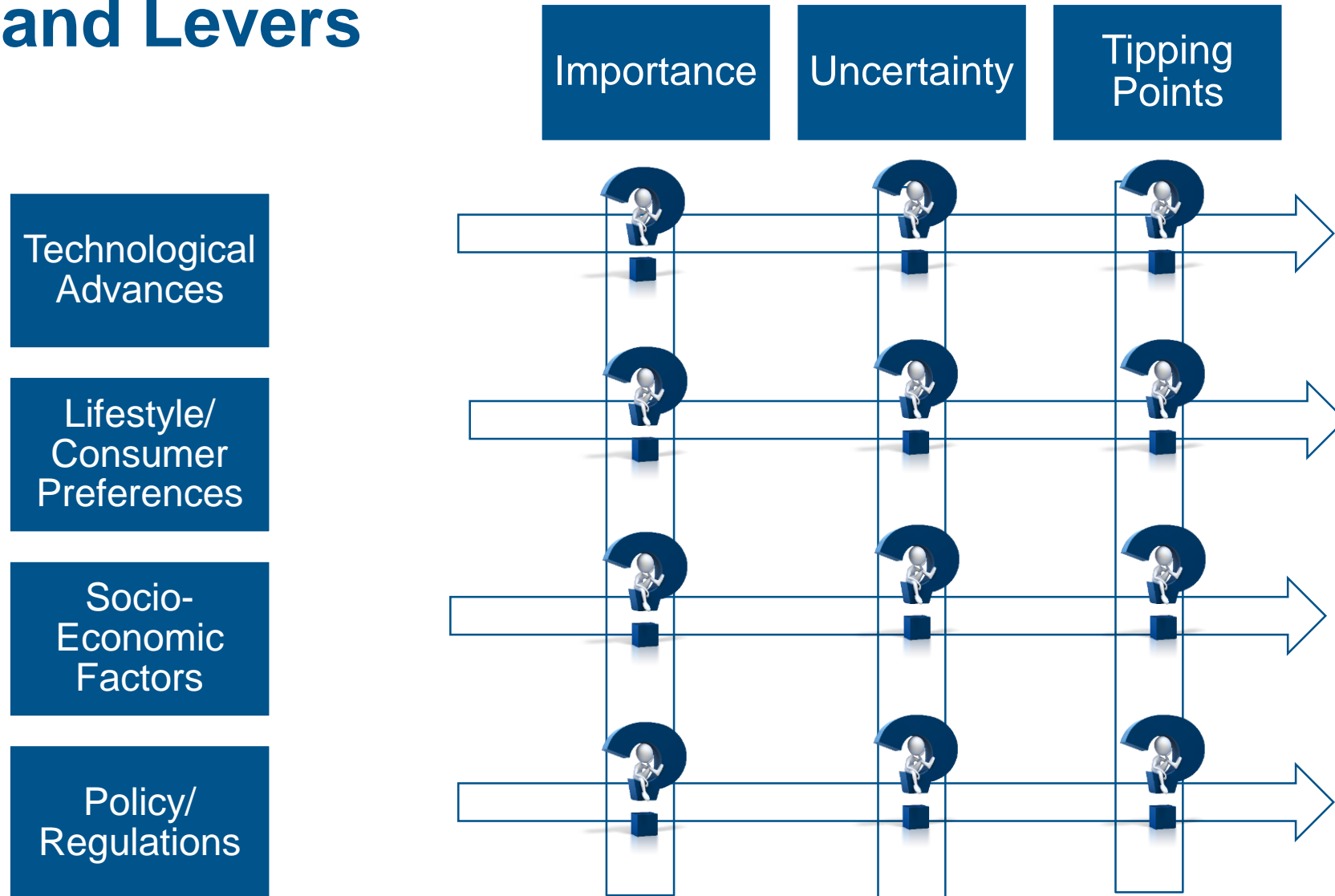


Outcomes

congestion... reliability...
safety... quality of life...



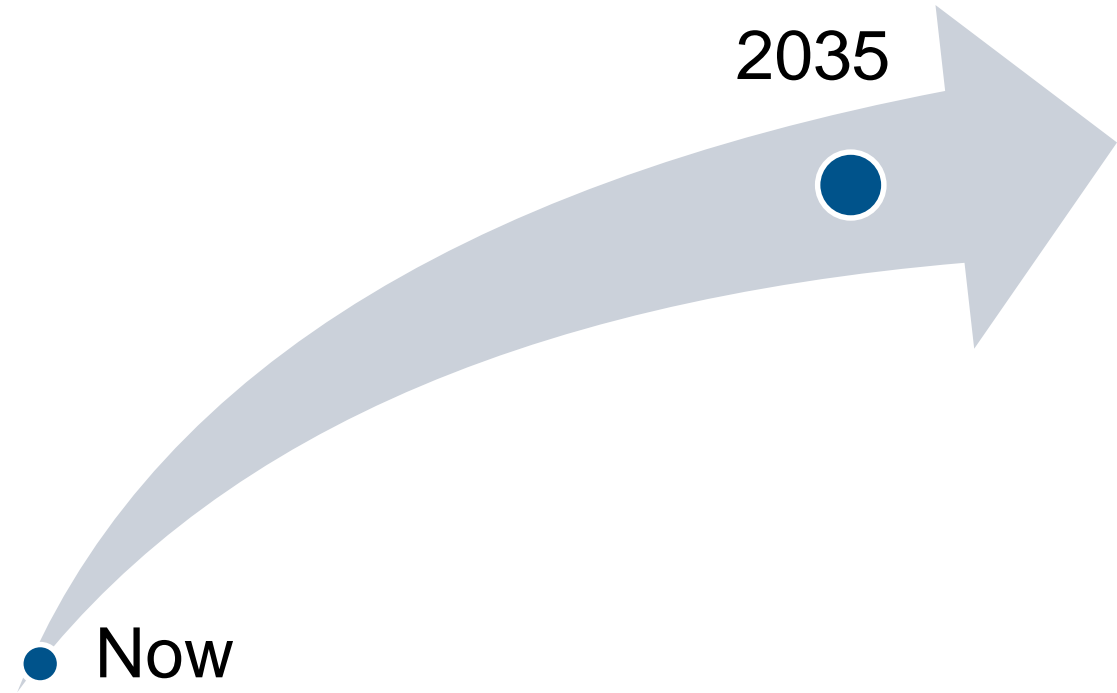
Forces and Levers



- *... fuel sources.. energy systems ... climate conditions ... funding ...*

Scenario Time Horizon

- Near enough to be relevant
- Far enough to be visionary
- Capture the trajectories
 - Tipping points
 - Trends



Tipping points include watershed events or “critical mass” evolutionary shifts that indicate a significant change in direction or magnitude.

Scenario Development Ground Rules

- DO NOT attempt to predict the future
- DO NOT try to pick winners
- DO envision several possible futures
- DO factor in revolutionary change, but also adaptation





4. Frame and Tailor the Scenarios

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2035 CV/AV Scenarios

Enhanced Driving Experience

Managed Automated Lanes

AV lane networks

AV travel is consolidated to a large-scale lane network with significant consumer adoption

Ultimate Traveler Assist

Ultra-Connectivity

AV adoption stalls, CV becomes ubiquitous

Baseline

Baseline

Minimal Plausible Change

Accounts for advances in safety technology, TSMO and mobility services

Driver Becomes Mobility Consumer

Niche Service Growth

High AV/CV in certain cases

Niche applications for CV/AV dominate the landscape

Competing Fleets

Automated TNC fleets compete

Level-4 AV is safe for most trips, travel is dominated by competing fleets

Integrated Automated Mobility

Automated mobility-as-a-service

High automation, strong public-private partnership for system optimization

Trajectories towards CV/AV Advancements

TODAY (circa 2018)

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in safety technology,
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Key Uncertainties

Connectivity

What percentage of vehicles can both transmit and receive information on the transportation system and on surrounding vehicle movements, and what kind of information are they transmitting?

Automation

What SAE levels of automation are available and affordable, and in what areas can they operate?

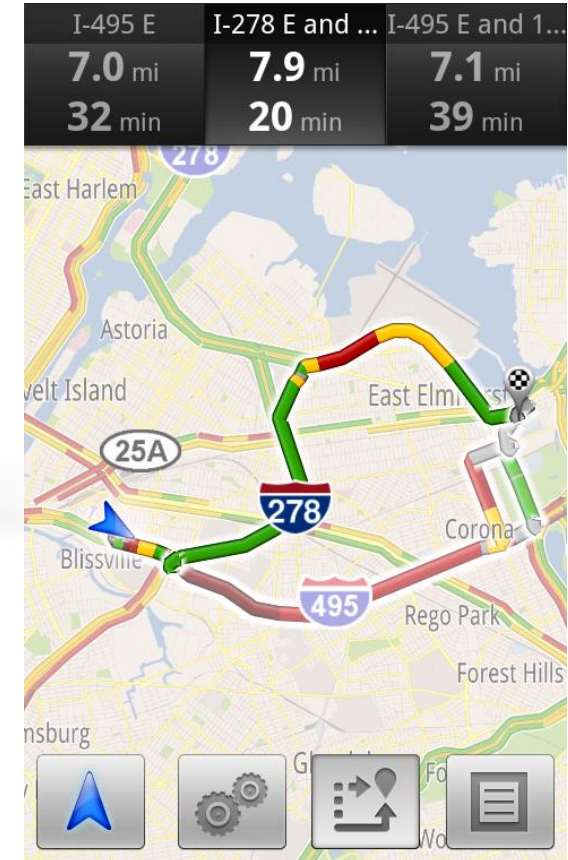
Cooperation

To what extent do agencies and companies adjust their operational practices and policies in accordance with other entities? Is there integrated payment, synchronization in schedules, multi-modal infrastructure development, etc.?

Scenario Name	Uncertainty Ratings			Description
	Connectivity	Automation	Cooperation	
Baseline				Minimum change beyond currently available technology and investments already in motion
Niche Service Growth				
Overall System				Innovation proliferates, but only in special purpose or “niche” applications
Niche Service Areas				
Ultimate Traveler Assist				CV technology progresses rapidly, but AV stagnates
Managed Automated Lanes				
Overall System				Certain lanes become integrated with CV and AV
AV lanes				
Competing Fleets				TNC-like services proliferate rapidly, but do not operate cooperatively
Automated Integrated Mobility				On-demand shared services proliferate and integrate with other modes via cooperative data sharing, policies, and infrastructure

Common Assumptions

- Mobile tech & mobility apps advance (multimodal routing, real-time travel info)
- 5G connectivity almost nationwide
- International V2X standards enable interoperability (automakers, construction companies, technology vendors, etc)
- Rigorous cybersecurity testing, industry-standard security systems



Baseline

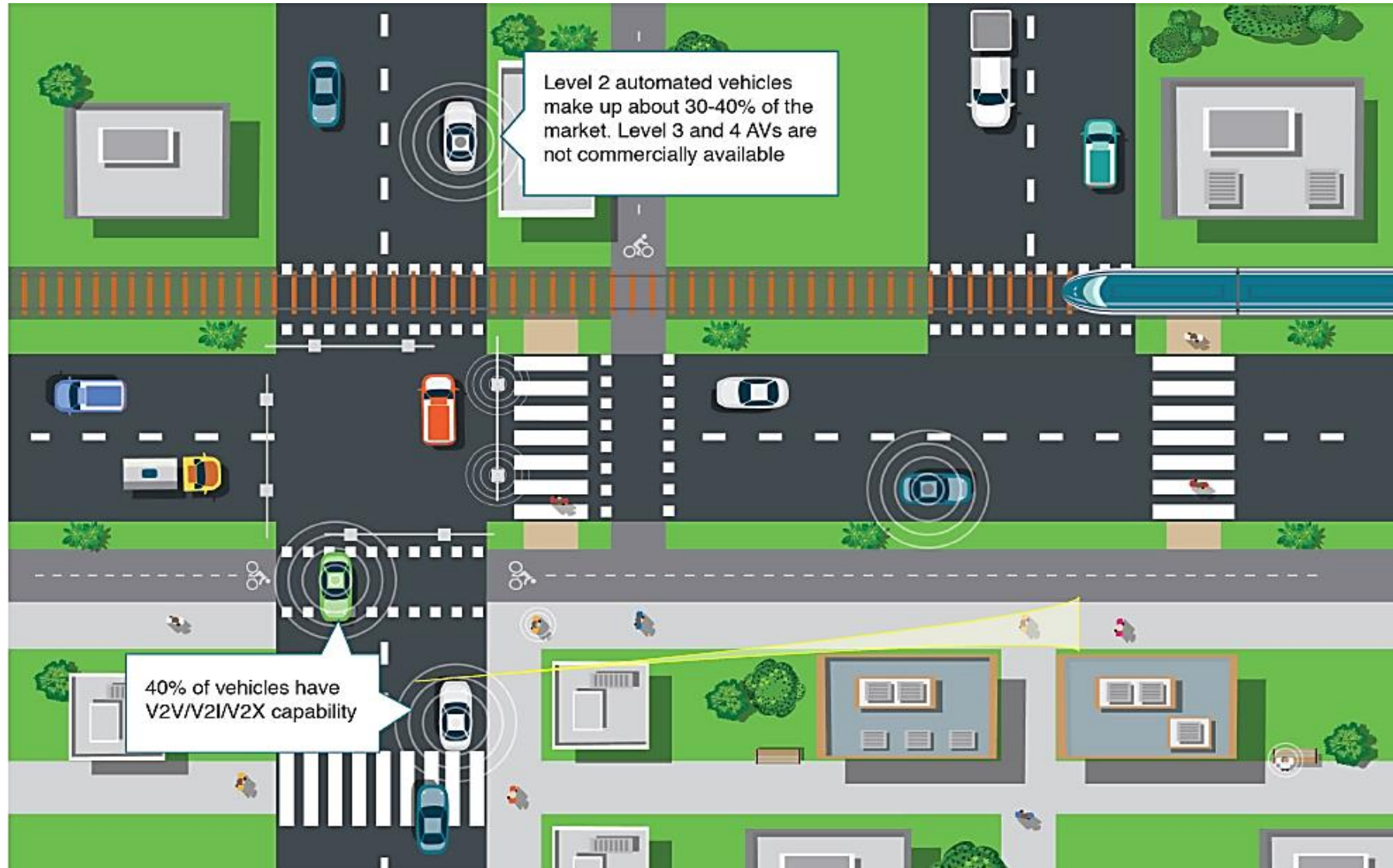
Trends

- **Current tech improves**
- Level 2 AV: 30-40% of the market
- Level 3-4 AV: not commercially available
- 40% of vehicles V2X capable
- 5-10% of trips via mobility-on-demand, up to 20% in major cities
- Pooled rides 0%–40% depending on region
- Real-time travel info near perfect
- Online retail/ same-day delivery grows

Impacts

- Safety improves (urban, affluent regions)
- Urban car ownership declines modestly
- Truck freight costs decrease
- Modest freight shift to truck from rail
- Urban truck/ drone delivery advances

Baseline



	Baseline
Potential new investments	<ul style="list-style-type: none"> • Increased infrastructure maintenance (eg lane markings)
Risks to current investments	<ul style="list-style-type: none"> • Some safety investments may no longer be necessary
Key local issues	<ul style="list-style-type: none"> • CV/ AV signal improvements, lane marking, signage, charging stations • Roadway maintenance • Bicycle / pedestrian compatibility • TNC/ shared use policy • Impact on Complete Streets, Vision Zero, other programs • Transit ridership impacts (shared mobility, vehicle ownership, land use) • Funding • Opportunity costs

Niche Service Growth

Trends

- **Level 4 AV in controlled, contained places**
 - campuses, office parks, retirement communities, downtown districts, first/last mile shuttles, airports
- Technology adoption outside niche areas same as Baseline
 - Level 2 AV: 30-40% of the market
 - 40% of vehicles V2V/ V2I/ V2X capable

Impacts

- Similar to Baseline but niches have better access, safety, and reliability.
- Freight impacts uncertain, not clear if niche services add benefit
- Niches gain competitive edge, attract jobs and residents.
- Niche visitors gain comfort with AV
- Niches are testbeds for new tech

Niche Service Growth

Level 4 automation exists in niche applications, but not in the general system, because of certain barriers: cost, inability to deal with adverse weather and unpredictable/unmapped conditions

Common niches: college campuses, office parks, airports, first/last mile shuttles, downtown business districts, islands, other cordoned areas



	Niche Service Growth
Potential new investments	<ul style="list-style-type: none"> • New transportation hubs • Freight fleet/platooning
Risks to current investments	<ul style="list-style-type: none"> • Reduced gas tax revenues • Weight limits for long-span bridges from truck platooning
Key local issues	<ul style="list-style-type: none"> • Curb space management, parking policies, zoning in niche areas • Freight facility investments • Transit connectivity within/ among/ outside niches • Transition zones around niches • Management of zero occupant vehicles • Enabling pilots and tests, interpreting results in context • Mixed traffic (human / machine operated) • Interactions with vulnerable road users

Ultimate Traveler Assist

Trends

- **CV takes off**
 - 85% of all vehicles have V2X capability (mix of DSRC and 5G)
 - Shared mobility similar to Slow Roll
 - AV similar to Slow Roll
- Ubiquitous, seamless public transit connectivity (in cities that invest) eliminates wait times and first/last mile gaps
- CV driving easier, safer (handling, navigation, finding parking, etc)
- Freight platooning widespread

Impacts

- Congestion nearly eliminated
 - Real-time routing, parking assist, dynamic pricing incentives, truck platooning, etc.
- Massive improvement in safety
 - 80% reduction in crashes
- Increased transit in cities with connected fleets
- Abundant real-time data transforms planning and operations
 - Informs travel demand management, system operations, integrated corridor management

Ultimate Traveler Assist

85 percent of all vehicles have V2X capability through a mixture of DSRC and 5G cellular

AV technology that exists or is in development in 2017 is refined and brought to market at a modest pace.

- Level 2 AVs make up about 30 to 40 percent of the market.
- Level 3 and 4 AVs are not commercially available

Traveler information is easily accessible and near-perfect in terms of latency and multimodality.



	Ultimate Traveler Assist
Potential new investments	<ul style="list-style-type: none"> • Data collection and management tools, staff capacity • Designated infrastructure for CV • Subsidized in-car technology/ retrofits • New revenue streams from dynamic pricing, other mechanisms
Risks to current investments	<ul style="list-style-type: none"> • Keeping up with ITS infrastructure investments • Traffic model assumptions, flexibility re: lane capacity, tripmaking, land use
Key local issues	<ul style="list-style-type: none"> • Zoning, access management policies to control travel flows • Seamless, instant public-private data sharing (construction, incidents, travel flows, etc) • Coordination with law enforcement • Developing common functional class systems • Interactions with vulnerable road users • Equitable access to opportunity

Managed Automated Lanes

Trends

- **AV-only networks on key corridors**
- Vehicles cannot be driven autonomously outside of designated lanes
- 50-60% of vehicles automated
 - Level 2 AV: 30-40% of market
 - Level 3 AV: 20% of the market
 - Level 4 AV: commercially available but rare
- 75% of freight miles automated
- AV lane operators manage speeds
 - Reduces congestion, increases energy efficiency
- Shared mobility, transit use similar to Slow Roll

Impacts

- Generally safer, less congested, cleaner
- Value of drive time improves
- Access to central business districts boosts urban economies
 - But downtown parking and congestion rise with influx of drivers.
- Some highway AV lanes extend to arterials
 - Enables suburban growth, more VMT, longer trips
- Intercity freight grows
- Some diversion from rail to truck.

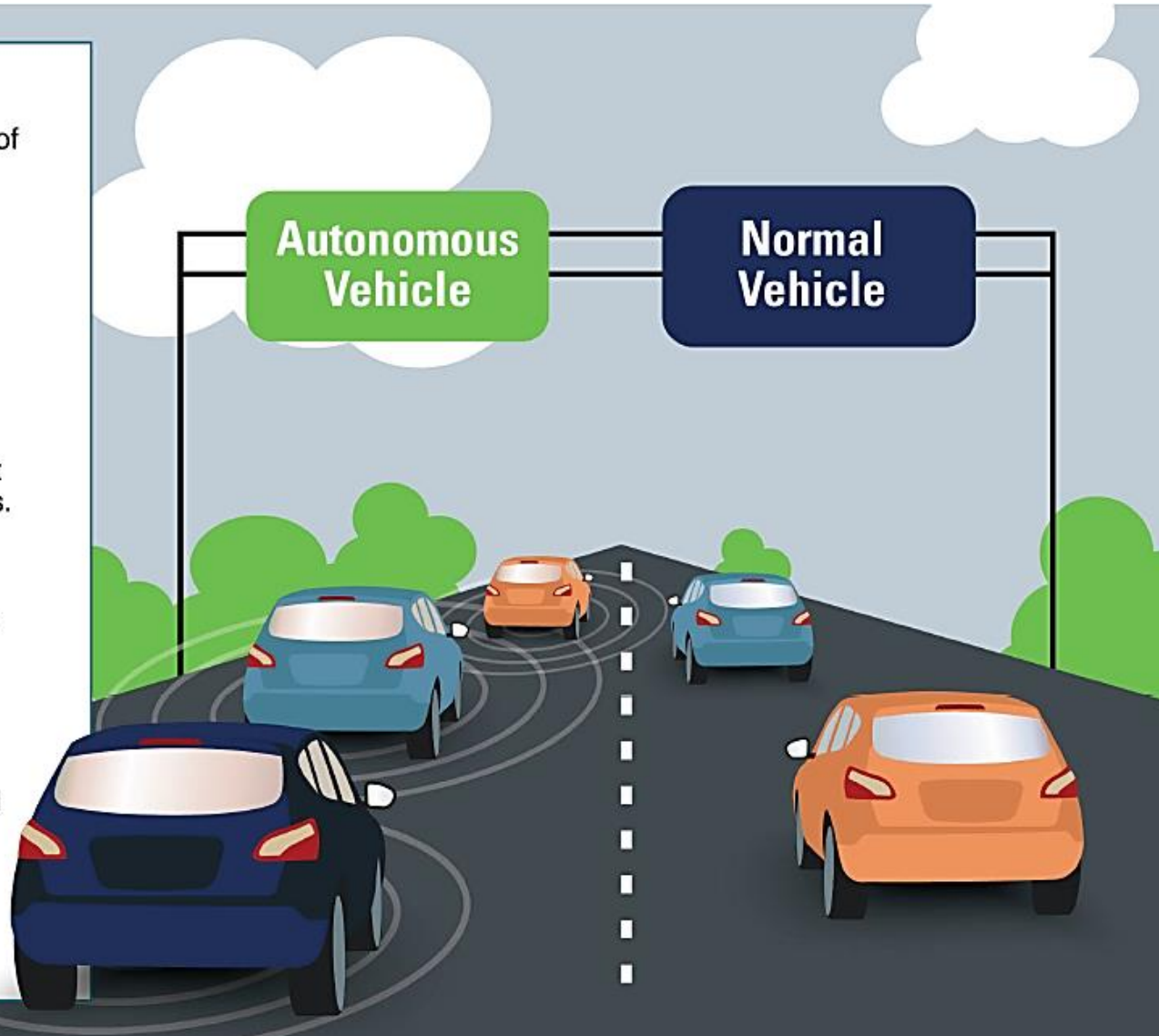
Managed Automated Lanes

50 to 60 percent of vehicles have some form of automation.

- Level 2 AVs make up 30-40 percent of the market overall.
- Level 3-4 AVs make up 20%, but are rarer since they offer few advantages over lower level AVs in this context of fixed-speed AV lanes.

75 percent of all vehicles, including all AVs, have V2X capability that allows them to communicate immediate safety information to other CVs

Freight fleets are highly connected and automated with 75 percent of freight highway miles being Level 3 or 4; platooning is nearly ubiquitous.



Managed Automated Lanes

Potential new investments

- **Data collection and management** tools, staff capacity
- **Downtown parking management**

Risks to current investments

- Ineffective data collection/ management structures
- Potential reduced transit demand

Key local issues

- Managing bottlenecks at the extremities of the network
- First- and last-mile access
- Downtown traffic, parking, curb space management
- Prioritization, pricing policies for AV corridors
- Transit's role in the system
- Interactions with vulnerable road users
- Equitable access to opportunity

Competing Fleets

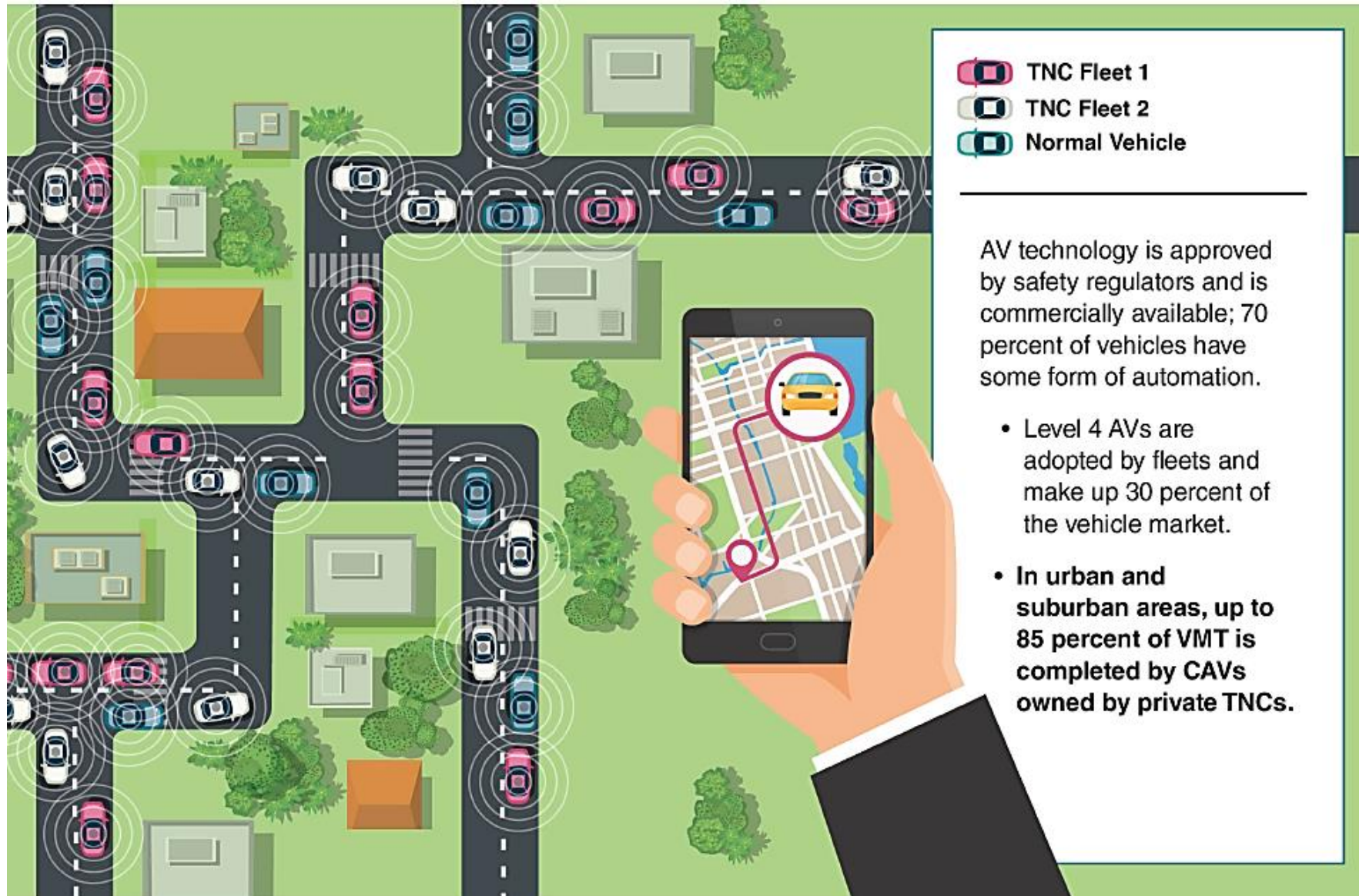
Trends

- **Litany of different services operates independently and competitively** with no cooperation or centralized management.
- TNCs automate fleets
 - Slash costs, vastly increase market share.
 - Up to 85% of urban/ suburban VMT is generated by TNCs operating AV fleets.
- Most vehicles connected and automated at some level
 - AV Levels 2-4: 70% of market
 - V2X capability: 75% of market
- Urban/ suburban vehicle ownership drops
- All TNC fleets and most private AVs are electric
- EVs, charging stations proliferate

Impacts

- Urban/ suburban VMT, congestion rise
 - Sharp drop in transportation costs
 - New travel by non-driving populations (former transit-dependent + empty VMT)
- Emissions impact uncertain
 - More EVs, but higher VMT.
- Safety improves where AV markets grow
- Accessibility generally improves
- Public transportation is effectively shifted to the private sector
 - Traditional rail and bus riders shift to cheap, flexible TNCs
- AV truck freight grows, costs drop

Competing Fleets



	Competing Fleets
Potential new investments	<ul style="list-style-type: none"> • EV charging stations • CV infrastructure • Subsidy agreements / partnerships
Risks to current investments	<ul style="list-style-type: none"> • Transit operations • Roadway wear and tear
Key local issues	<ul style="list-style-type: none"> • Managing access, street space • Data management • Recharging infrastructure • Re-use of parking areas • Loss of parking revenue • Equity • Freight facility investments • Interactions with vulnerable road users • Local AV regulations • Local transit viability

Integrated Automated Mobility

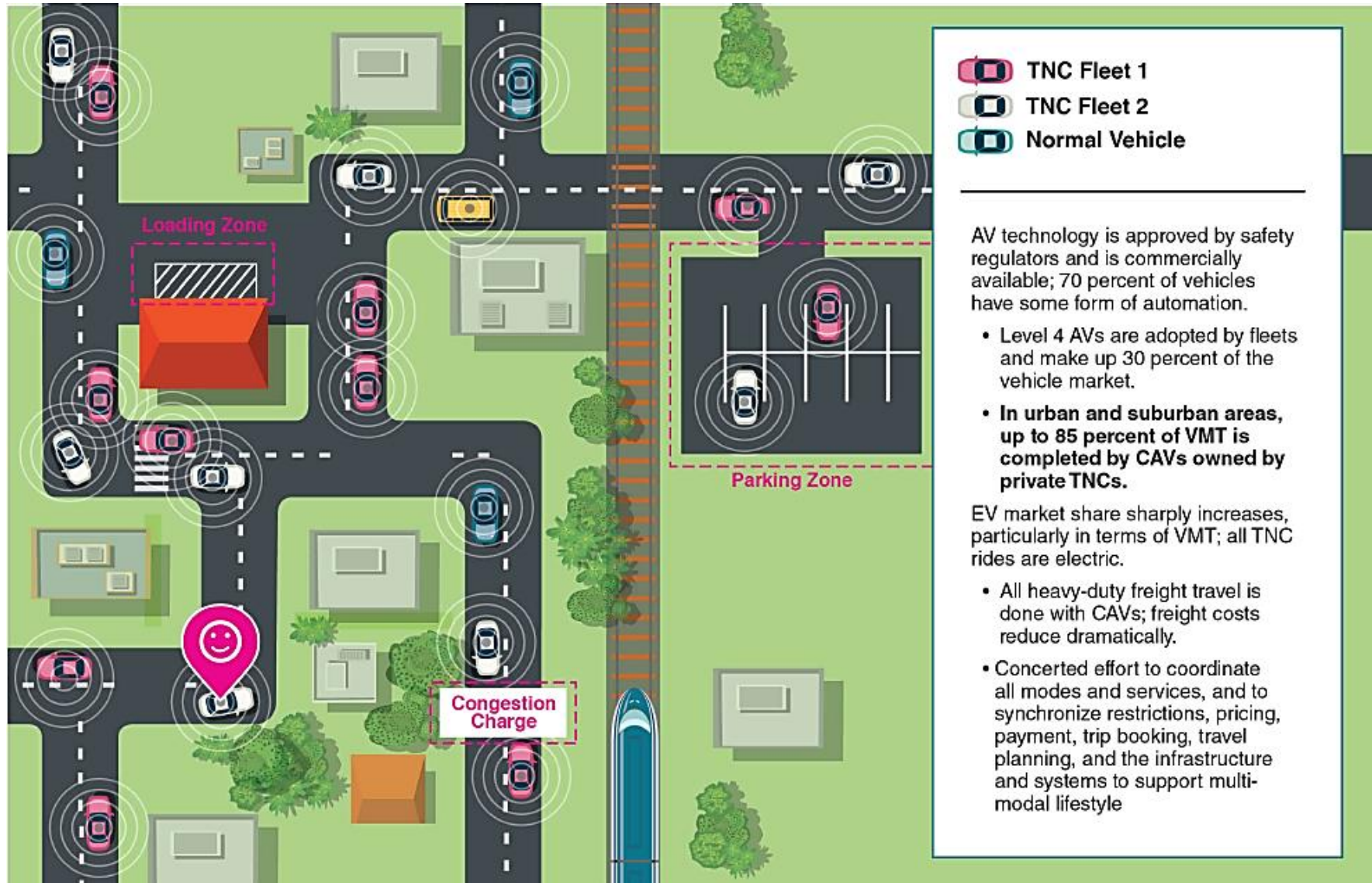
Trends

- **Strong public sector leadership fosters system optimization**
 - Multimodal travel coordinated through dynamic pricing and other mechanisms
- Like Competing Fleets in other ways:
 - Up to 85% of urban/ suburban VMT is generated by TNCs operating AV fleets.
 - AV Levels 2-4: 70% of market
 - V2X capability: 75% of market
 - EVs and charging stations proliferate.

Impacts

- Increased travel, esp. by non-drivers
- VMT and congestion levels vary depending on policy levers such as real-time traffic pricing.
- Public transit rises in cities that leverage integrated automated mobility.
 - In others transit is cannibalized by cheaper TNCs
- Vehicle ownership, emissions, travel time drop
- Safety, accessibility rise
- New freight delivery models eliminate big trucks in some cities.
- Urban parking all but eliminated
- Once-inaccessible neighborhoods attract new residents, businesses

Integrated Automated Mobility



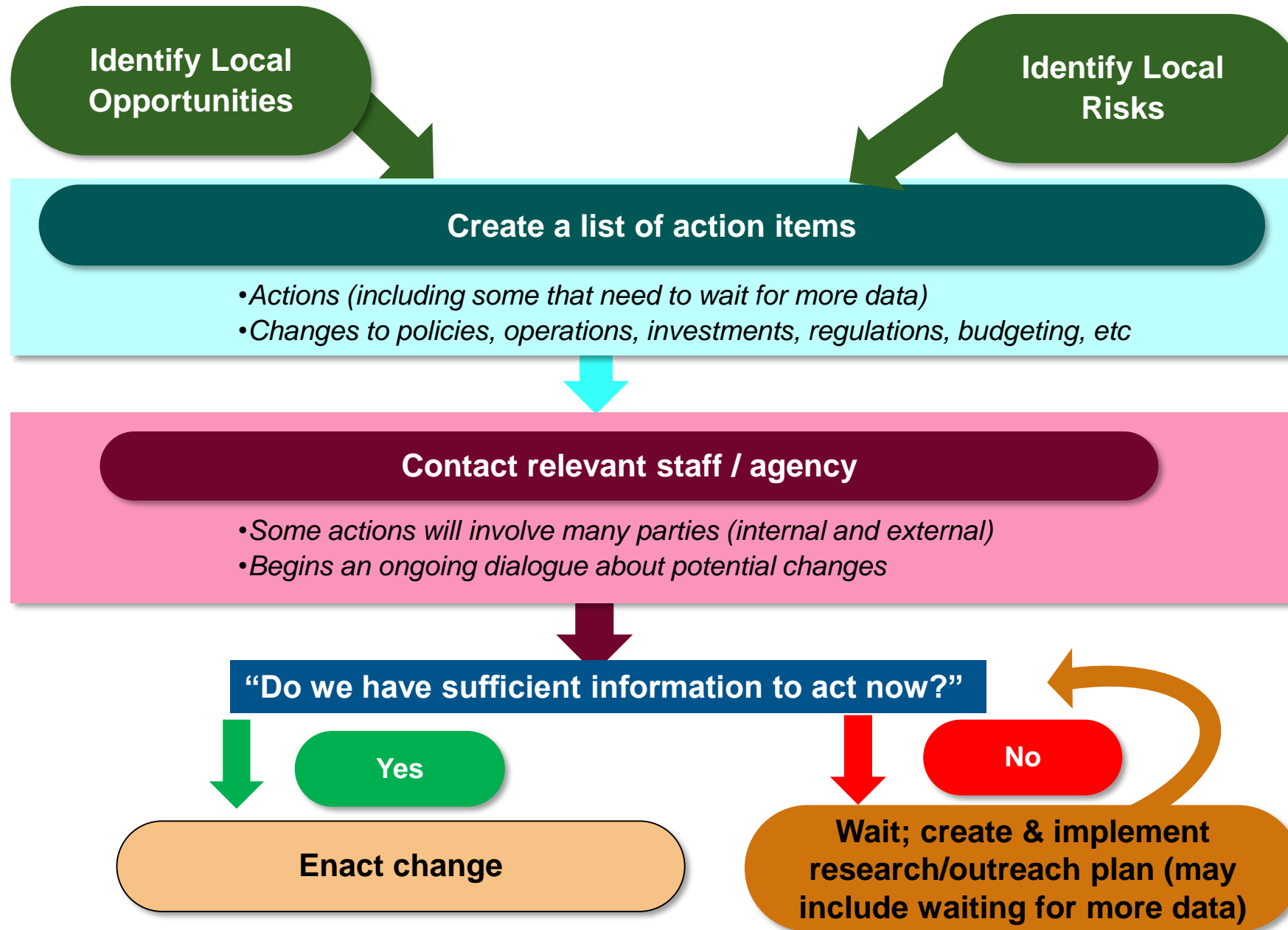


	Integrated Automated Mobility
Potential new investments	<ul style="list-style-type: none">• EV charging stations• CV infrastructure• New transit operational models• New land uses for areas formerly dedicated to parking
Risks to current investments	<ul style="list-style-type: none">• Public transit if not leveraged
Key local issues	<ul style="list-style-type: none">• Pricing• Zoning/Curb space management• Public transit management• Workforce changes• Loss of parking revenue• Potential for affordable housing by unbundling parking• Equity, vulnerable road users• Public safety



5. Incorporate Scenario Results into Decision-Making

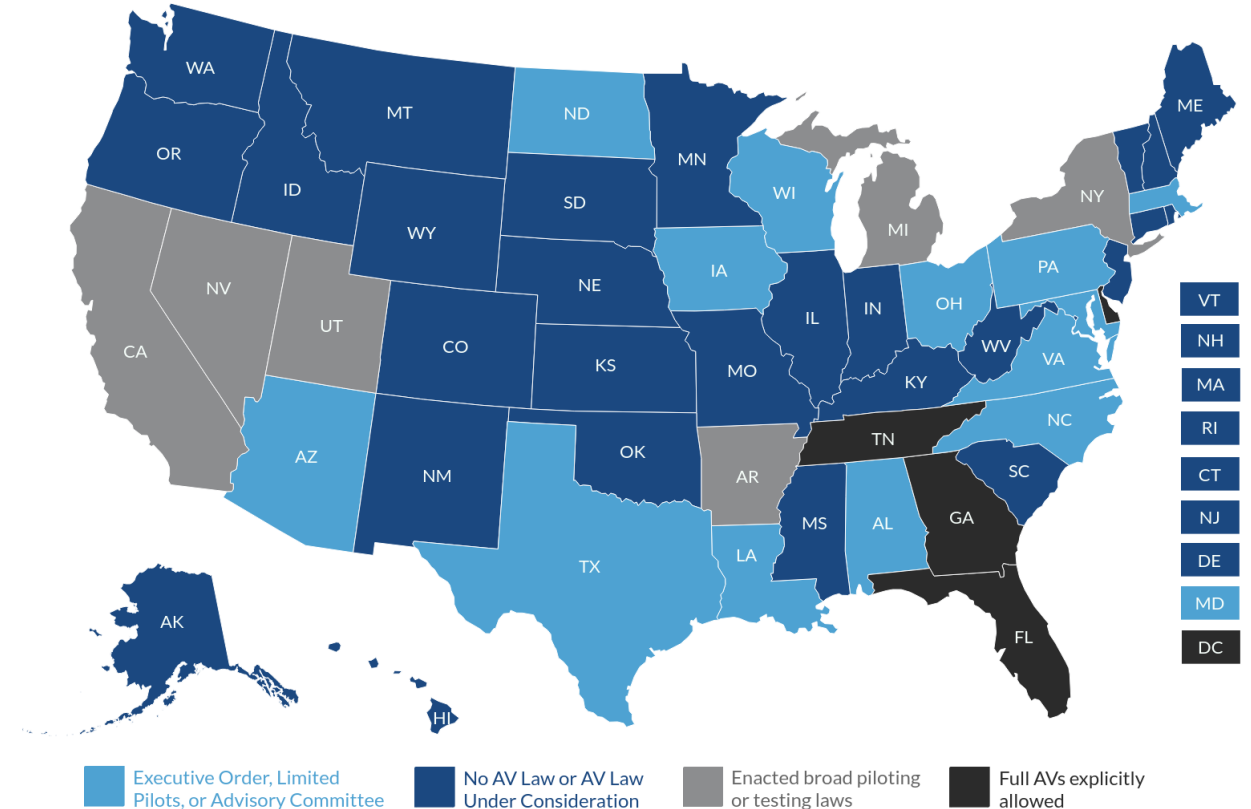
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- *Create an action list and prioritize*
- *Adjust plans, policies, operational strategies, and investments*



Levers: State/ Regional/ Local Policy

- Technology restrictions
- Technology incentives
 - EV readiness
 - Parking policy
 - Street space/ curb policies
 - Housing codes
 - VMT / travel pricing
 - Occupancy-based incentives
- Infrastructure investments
- Operational strategies
- Public transit investments

Categories of AV Legislation Across US



Source: National Conference of State Legislatures and individual state legislation¹⁷

Created by:
Ann Henebery / Eno Center for Transportation

- **Source: Adopting and Adapting State Policies for Automated Vehicles, Eno Center for Transportation www.enotrans.org**



6. Monitor industry and policy developments

- Monitor industry and policy developments related to CV and AV, and adjust plans where necessary

Scenario Building Blocks



Forces

environment... economy...
society... technology...



Levers

Investments in
infrastructure conditions...
travel choices... equitable
access



Outcomes

congestion... reliability...
safety... quality of life...



Technological Forces

- **Cybersecurity**
- **Machine learning**
- **Rapid sensorization**
- **EV battery and charging**
- **Mobile platforms**
- **Mapping**
- **New modes (hyperloop, drones, scooters)**
- **Vehicle design/ decision support tech**
- **5G wireless technology/ DSRC adoption**
- **Big data analytics**
- **Virtual reality**
- **Industrial automation/ manufacturing**

Consumer Preferences

- Tech acceptance
- Vehicle ownership
- Sharing economy
- Pedestrian activity
- Bike/ scooter preferences
- On demand service trends
- Urban living
- Eco-consciousness
- Working habits
- Trust in government/ regulation

Socio-economic Factors

- Business models (MaaS)
- Aging population
- Nondriving population
- Housing prices
- Employment levels
- Workforce trends
- Market forces (fuel, materials, international leapfrogging)
- Smartphone adoption/ evolution
- Liability/ insurance frameworks
- Urbanization
- Immigration

Levers: National/ Global Policy

- Trade policy/ tariffs
- International carbon trading
- International regulations on engines or other technology
- Tax incentives and credits
- Technology mandates (such as DSRC on light-duty vehicles)



"Sure, it's a great invention, but does it comply with all government guidelines?"



Outcomes – *Place Your Goals Here*

- ✓ **Safety**
- ✓ **Infrastructure Condition**
- ✓ **Congestion Reduction**
- ✓ **System Reliability**
- ✓ **Freight Movement and Economic Vitality**
- ✓ **Environmental Sustainability**
- ✓ **Reduced Project Delivery Delays**
- ✓ **Equitable Access/ Mobility**

For More Information ...

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