Scenario Planning for Transportation Technology

Planning for an Uncertain Future

Scenario planning for emerging technologies involves an informational and direction-setting process that aims to create more informed decision-making about current and future transportation priorities and investments.

Scenario planning enables public agencies to navigate the uncertain impacts of emerging technologies. By adapting commonly used scenario planning techniques for emerging technology adoption such as connected and automated vehicles (CAVs), agencies can work with stakeholders and communities to develop robust scenarios of how various future forces interact. These include rate of technological development, mode of deployment, public acceptance and adoption, policy and regulatory requirements, and other forces. Scenario planning for these technologies helps agencies explore and prioritize a wide range of possible responses, understand the risks and opportunities under different conditions, and craft adaptive strategies for implementation. This white paper describes cases studies that serve as illustrations of informational and direction-setting processes undertaken by public agencies across the US that aim to create more informed decision-making about current and future transportation priorities and investments.

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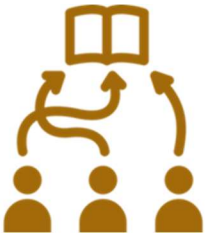
KEY STRATEGIES



Scope the Scenario Planning Effort, Engage Partners, & Craft a Common Vision. Scenario planning helps agencies to build relationships and forge partnerships that can strengthen their effectiveness and build their capacity. Before being able to derive plausible scenarios, the state, regional, and local partners need to collaboratively frame the analysis by defining the scope of the scenario development process and establish a common understanding to build upon.

Establish a Collective Baseline and Influential Trends. A clear baseline scenario, one that explains how the current transportation system would evolve without public intervention, forms an essential basis for comparing scenarios and implementation strategies.

Develop Public Engagement Materials to Educate and Solicit Information from the Public. Translating information into layman terms will help communicate technical and complex concepts to constituents. Interactive public engagement can solicit insights from constituents on how they will use the technology and reveal sentiments on the status of public acceptance

Formulate Scenarios That Are Well Informed by Technology Experts. Public agencies can work with industry technology developers and deployers for mutually beneficial information exchange. This allows truer assessment of real maturity and readiness of each technology as well as applications and cost to cost to users.

Evaluate Scenario Feasibility against Constraints. Identify constraints to implementation by identifying feasibility indicators. Scenario planning can help transportation practitioners and policymakers better prepare for the future by encouraging an examination of different future conditions; this forecast should get beyond just an extrapolation of current trends and enhance the understanding of tradeoffs.

Identify Strategies for Realizing Scenarios. Working collaboratively with partners, develop a future blueprint focusing on key scenarios, identify potential actions or policies to be taken for implementation, and develop a plan for monitoring progress. This process can also help agencies to convey critical information to policy-makers and elected officials who make future investment decisions.

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Planning for the Future of Transportation

The word "futurology" tends to conjure images of science fiction tropes, like spaceships, clones, and time travel. But futurology, also known as *futures studies*, is a practice and field, defined as the "systematic attempt to predict future developments by an intensive study of historical and current trends."[i] Futures studies straddle the line between academia and business, with a goal of merging social sciences, mathematics, engineering, and business management and strategy.

Methods developed by futurists have been put into practice by governments and businesses. An explosion of these methods took place in the mid-20th century. For instance, the Project RAND team developed the Delphi method in the context of future weapon long-range planning following World War II[ii]; this method is a structured communication technique that convenes a panel of anonymous experts to converge upon forecasts or decisions.[iii] The Central Intelligence Agency has employed another methodology, the cross-impact method, which interacts multiple possible events, identifies whether they are positive or negative relative to each other, and determines which events are most probable[iv], to predict political instability in foreign regimes.[v] The foundations of scenario planning can also be attributed to the RAND Corporation, and the concepts were pioneered in practice by militaries and large companies.[vi] Scenarios are a suite of narratives representing plausible situations that are designed to help policy-makers and firms prepare strategies to navigate change.[vii]

Transportation planners are futurists at heart, concerned with how existing and emerging trends in demographics, business and natural environments, and technology may shape future travel demand and needs. To this adequately, planners can't select one normative vision to plan for, neglecting the infinite number of other possible futures. In today's practice, long-range transportation planning is a derivative of scenario planning. In the United States, the process takes on a normative scenario planning approach by envisioning a preferred future scenario and backing into a set of strategies and investments that could help achieve that chosen outcome. The process is linear, beginning with the consideration of a few possible futures, selecting a preferred future, and then setting goals. The preferred future is usually quite optimistic, assuming population and economic growth. In contrast, exploratory scenario planning is cyclical and more pragmatic and cautious. The process includes understanding driving forces of change; crafting scenarios; monitoring industry, policy, and technology developments; and including diverse stakeholders to consider multiple possible futures, evaluate risks and opportunities, and shape tactics and policy. Though scenario planning as a term has been used by transportation practitioners since the 1990s, only the most recent applications are exploratory in nature, posing questions around emerging challenges like rising fuel costs, climate change, catastrophes, economic downturns, trade, and technology.[viii]

Even then, this new wave of scenario planning mostly takes broad outlooks, synthesizing trends in freight, climate, technology, and demographics to generate divergent scenarios. For instance, the National Cooperative Highway Research Program (NCHRP) sponsored a series of reports on strategic transportation issues in 2012. The final one pioneered a scenario-development and assumption-testing stakeholder workshop, generating these four scenarios:

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- *Momentum*: Incremental population change, without major demographic, economic, technological, or policy shifts. Increased vehicle-miles traveled (VMT) but lower per-capita VMT, and minor decreases in congestion.
- *Technology Triumphs*: Innovations increase lifespans, reduce carbon footprints, connect people, and increase mobility. Automated vehicles change how people travel, and people travel less as virtual commuting and socializing rise in popularity.
- *Global Chaos*: Global financial instability, a US recession, climate change drive jobs, food, and oil insecurity and widespread unemployment. Transportation revenue decreases as many can no longer afford to drive personal vehicles.
- *Gentle Footprint*: Climate action is executed, culture shifts towards environmentalism, and the US dramatically reduces energy consumption. Transportation investments skew multimodal and driving decreases.[ix]

The research done for this project also incorporated the four scenarios into a quantitative model, using Atlanta, Boston, Detroit, Houston, and Seattle as case studies. The project was designed to illustrate how a similar process could support long-range planning, use existing planning models, formalize the consideration of uncertainty in the planning process, and facilitate participation in the planning process. Each scenario was designed as an extreme case, meant to inspire public officials to think through what they might do if they did realize they were on the path to one of those futures.

The Delaware Valley Regional Planning Commission (DVRPC) used this framework in their most recent plan development process, generating five what-if scenarios with varying demographic trends, development patterns, travel demand shifts, infrastructure needs and capabilities, and economic projections. One of these scenarios considers the impacts of technology to the extent that new mobility services alter travel demand, 3D printing and other freight innovations lower freight VMT, and alternative energy reduces energy costs. Taking a broad perspective enabled the working group to recommend sweeping investment priorities in infrastructure preservation and active transportation and strategies such as public-private coordination, evacuation plans for carless households, and shared mobility policies.[x] These types of recommendations are powerful for shaping region-wide priorities that metropolitan planning organizations (MPOs) are concerned with. However, high-level scenarios limit the quantity and quality of actionable recommendations for investment decision support around a singular issue. For instance, having only one scenario focused on technology as a category in itself—rather than considering the functions individual technologies provide—cannot produce recommendations on what technologies a state DOT should further research or implement, not to mention when or where.

For a state DOT seeking practical and action-oriented technology implementation recommendations, the scenario planning approach can and should be adapted to a narrower universe. Emerging transportation technologies and scenario planning are a perfect complement because the interactions that the technology sector and the transportation sector will produce are highly uncertain but likely demand at least some degree of public sector intervention to guide the realization of a more equitable, sustainable, and mobile future.

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For instance, a 2017 survey of state DOTs found that 36% of respondents were considering CAVs and their potential impacts using scenario planning or visioning, which demonstrates that leading state DOTs see value in pioneering CAV scenario planning. However, the survey also found numerous barriers to CAV scenario planning: the challenges inherent in modeling VMT and mobility impacts, lack of understanding of the technology, the fast-paced development of the industry, reluctance of the private sector to share needs, and resulting planning uncertainties.[xi] This exemplifies the need for more state DOTs to contribute to the development of CAV scenario planning so that agencies can coalesce around their respective findings and demonstrate how scenario planning can translate into technology implementation and strategy.

The remainder of this paper will present pioneering examples of transportation agencies tailoring scenario planning to specific issues, such as freight, CAVs, and shared mobility, and using different methods to project impacts. Then, this paper will present Texas-specific environments suitable for tailored scenario planning. Because they align with identified gaps in current practice, the proposed environments represent key opportunities for Texas to advance the scenario planning literature and practice.

Scenario Planning Case Studies

The following case studies present a scan of the state of the practice in emerging technology integration with scenario planning. Some initiatives are still underway as of Spring 2019, while others have been completed within the last four years. The case studies focus on two key steps in the scenario planning process—stakeholder engagement and impact assessment—and the varied methods and approaches used, including expert interviews, workshops, and panels.

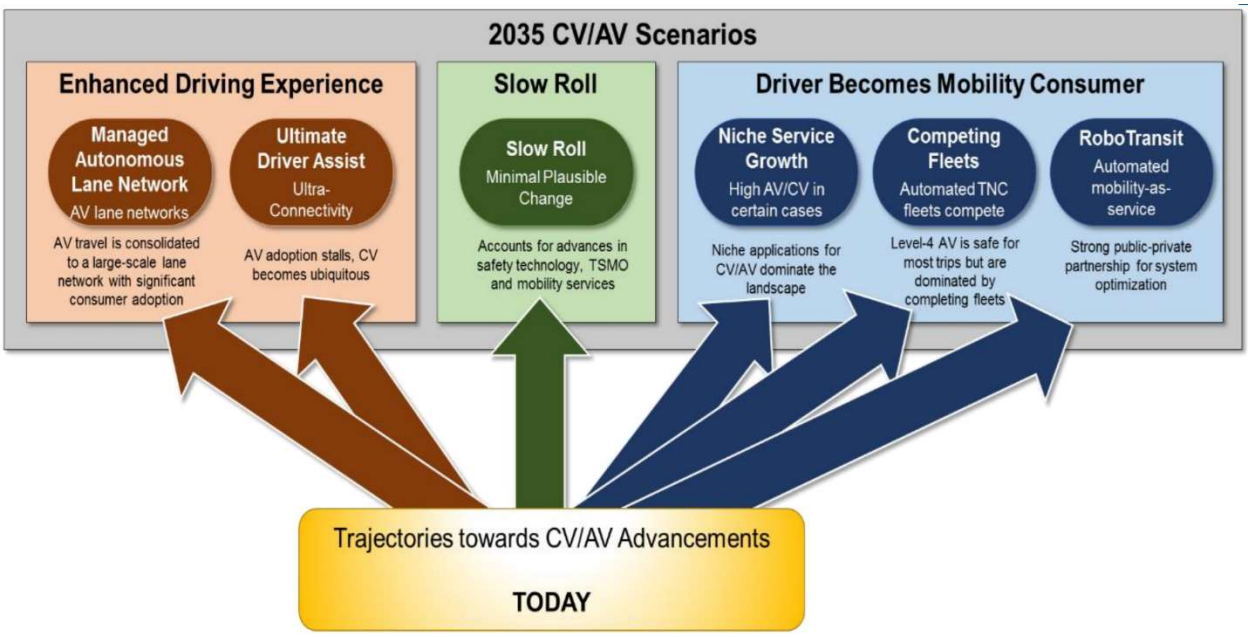

Figure 1: The Six FHWA CV/AV Scenarios

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National Initiatives

FHWA Scenario Planning for CAV Workshops. The Federal Highway Administration (FHWA) has led the application of the scenario planning framework to CAVs by developing preliminary scenarios that many subsequent efforts have drawn inspiration from. Their initiative has two objectives: to provide guidance for transportation planners on CAV scenario planning and to develop a framework for analyzing the costs and benefits of various scenarios.

To the first goal, FHWA recommended how to frame a scenario planning approach, especially for practitioners who may be unfamiliar with the method. They emphasize that scenarios are alternate futures that are a tool for agencies to use to evaluate their plans under different possible outcomes. FHWA advised that agencies forgo asking themselves "what do I have to do?" and instead ask, "what might happen if…" and "what do we as a community want?" Combined with a critical look at the assumptions that are made about various scenarios and outcomes, these exploratory questions can enable an agency to reduce their risk of overlooking some possibilities that the future may contain. FHWA held two workshops, convening representatives from cities, MPOs, and states, to develop six CAV scenarios and provide concrete recommendations for agencies looking to implement a CAV scenario planning process of their own. In the first workshop, FHWA invited people who were not traditional transportation planners, such as academics, analysts, and industry

Scenario Name	Scale Ratings			Description
	Connectivity	Automation	Cooperation	
Slow Roll				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 AV Lane Network				
Overall System				Certain lanes become integrated with CV and AV
AV lanes				
Competing Fleets				TNC-like services proliferate rapidly, but do not operate cooperatively
RoboTransit				On-demand shared services proliferate and integrate with other modes via cooperative data sharing, policies, and infrastructure

12/14/2017

Figure 2: The Assumptions and Descriptions behind the Six FHWA Scenarios

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representatives, with a goal of examining the characteristics and capabilities of CAV technology. In the second workshop, FHWA invited transportation practitioners to take preliminary scenarios; refine and tailor them to the questions and uncertainties posed by participants; and develop language around the drivers, levers, and tipping points.

FHWA named a few strategies for guiding workshop discussions. They asked participants to think about scenarios as trajectories between present day and the future, rather than a fixed point in the future. This was meant to inspire people to identify possible indicators that may present themselves in the near future that would signal the manifestation of a particular scenario or think about near-term actions they could take to enable a future scenario. The scenarios were also held at a time when FHWA sensed negativity and distrust of automated vehicles, and the workshops were a tool for examining what assumptions people were making about the future of autonomous vehicles (AVs). FHWA also emphasized the importance of making the workshops a flexible, nuanced discussion rather than a specific effort to predict the future. The publication of a final report from the FHWA initiative is in process.

Figure 3: Narrative from MnDOT Scenario 3 - Private Automation

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State DOT Examples

The following examples from other states illustrate what statewide action could look like.

Statewide CAV Workshops: MnDOT.

Minnesota Department of Transportation (MnDOT)'s CAV-X office has initiated a number of CAV planning and implementation efforts in line with a 2018 executive order signed by Governor Mark Dayton establishing the Governor's Advisory Council on Connected and Automated Vehicles. One such effort is a series of scenario planning workshops held between November 2018 and March 2019 to explore how CAVs could change transportation and life in Minnesota in the next 20 years. The workshops are intended to help MnDOT plan for and address various CAV scenarios.

The MnDOT team focused on four technology levers: automation, electrification, sharing, and connectivity. They crafted four scenarios by varying each of these levers to create different combinations of their respective adoption or maturity. The scenarios were inspired by FHWA's six scenarios, but were adjusted to fit Minnesota-specific environments, such as extreme winter weather events and rural populations.

Workshop participants mostly included practitioners from local governments and the private sector, some elected officials, and representatives from non-profits or advocacy groups. After forming breakout groups around one of the four scenarios, participants were asked to respond to a set of questions. These included what

Figure 4: MnDOT's CAV Workshop Scenarios

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impacts participants foresaw from each scenario, what the potential opportunities or challenges would have, and what actions could be taken to capitalize or address them. They asked questions such as "in order for us to make this opportunity come to fruition, what do we have to do today?" and "in order for us to mitigate this challenge what do we have to do today?" Then, they asked participants to group and prioritize strategies, while comparing them to current MnDOT CAV plans and strategies in order to determine how well the plans might support the scenario. Preliminarily, MnDOT is finding that the workshops tend to focus on the safety, equity, and accessibility of vehicles, particularly in for those who are disabled, live in rural areas, are elderly, or have limited ability to afford new vehicle technologies.

So far, MnDOT has not made plans to integrate workshop findings into a quantitative travel demand modeling process, but they have discussed adjustments to roadway and infrastructure design. Following the conclusion of the workshops, MnDOT will release a final report with trends and findings, synthesizing those findings with their current CAV strategic plan and their statewide transportation plan.

Figure 5: Narrative from MnDOT Scenario 3 - Private Automation

A DAY IN THE LIFE

Maketa leaves her St. Paul office and requests a ride on her phone. Within seconds, an electric AV pulls up in a nearby pickup lane, where many cars are taking in passengers. After wading through the waiting vehicles, she gets in for her ride out to Lake Elco. She takes out her book and begins to read – it could be a long ride, as congestion has made what was once a 30-minute commute into almost an hour. Many of Marketa's friends and relatives have their own automated vehicle and use them for everything from commuting to errands to transporting children and other family members. However, they too are frustrated with the increased congestion.

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	LRTP Goal	Slow Roll
		Minimum plausible change - Nothing beyond currently available technology and investments already in motion is adopted. (Baseline for comparison)
ACES Shares - 2035	*AVs – L2*	50 – 60%
	AVs – L3	0%
	AVs – L4	0% / 0%
	CVs in Fleet	40%
	EV Sales (urban/all)	15% / 5 – 10%
	Shared Trips (urban/all)	20% / 5 – 10%
1.	*Safety & Security*	Level 2 driver assist features (e.g. lane tracking, automatic braking) reduce fatalities and serious injuries.
2.	*Maintenance and Operations*	Truck platooning is common on rural interstate highways.
3.	*Mobility and Connectivity*	Mobility services reduce car ownership near urban cores, while increasing travel by elderly and disabled populations everywhere.
4.	*Economic Competitiveness*	Widespread use of real-time travel info reduces costs of congestion.
5.	*Community Livability*	
6.	*Environmental Stewardship*	Electrification trend continues, decarbonizing the transportation sector and reducing emissions.

Figure 6: FDOT Slow Roll Scenario

Statewide Leadership and Scenario Tailoring: FDOT. Like MnDOT, the Florida Department of Transportation (FDOT) used FHWA's six CAV scenarios as a starting point for a scenario planning initiative. In 2018, they produced a guidebook for MPOs, called *Guidance for Assessing Planning Impacts and Opportunities of Automated, Connected, Electric, and Shared-Use Vehicles*. The guidance document is intended to tailor an ACES-specific scenario planning approach so that MPOs can use the framework when updating their long-range transportation plans. The guidance maps each of the six scenarios to the 2060 Florida Transportation Plan's strategic goals to demonstrate how MPOs could do the same with their respective plans. The following figure shows how FDOT mapped their strategic goals to the "Slow Roll" scenario, and the full table can be found in the appendix.

As of March 2019, FDOT plans to hold workshops and web-based trainings to continue engaging MPOs in the state around the integration of scenario planning into their existing planning processes. They also plan to follow up with each MPO in Florida to understand what their region's needs might be with respect to the ACES and help them initiate a scenario planning process.

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Regional (MPO) Examples

MPO examples are presented to demonstrate what scenario planning and emerging technology implementation could look like.

Metropolitan Transportation Commission.

The Bay Area's Metropolitan Transportation Commission (MTC) is working on two initiatives that bring together scenario planning and emerging transportation technologies. The first is the Future Mobility Research Program, which MTC formed by joining forces with the Southern California Association of Governments, San Diego Association of Governments, and Sacramento Association of Governments. The program funds research to assess a range of emerging technologies, including ridesourcing and automated vehicles, and one of the primary objectives is to inform modeling assumptions about emerging technologies when integrated into the MPOs' respective planning processes.

One of the ways the study attempted to gather reasonable modeling assumptions for AV scenarios was by interviewing 22 subject matter experts using the Delphi survey method. Some of the outcomes the experts were surveyed on included the adoption timing, safety impacts, and other transportation system metrics. Another study the research program is funding will examine technology trends and use more exploratory methods to consider ways to account for technology trends, either by adding assumptions to their activity-based model or through higher-level, back-of-the-envelope projections. Another study underway is a survey to understand ridesourcing users and travel behavior.

The second initiative is the creation of a scenario planning process in 2018 called Horizon, which will support the agency's development of their next long-range plan, Plan Bay Area 2050. MTC calls their three exploratory scenarios the "three Futures;"

Variable – Fully Driverless Vehicles	Average Response	Standard Deviation
Vehicles Available for Purchase	2026	6 years
Relative Cost to Legacy Vehicle (%)	↓ 14%	25%
Consist of 50% of Urban Trips	2036	5 years
Consist of 90% of Urban Trips	2049	7 years
Resulting Increase in Freeway Capacity (%)	↑ 44%	41%
Resulting increase in Urban Street Capacity (%)	↑ 23%	22%
Distance from Home to Work (%)	↑ 31%	27%
Time Spent in Vehicle (%)	↑ 31%	23%
Percent of Trips that are Shared (%)	61%	24%
Percent of Trips by Empty Vehicle Circulation (%)	26%	18%
Congestion (worse 1 - 10 better)	6	2

Figure 7: MTC Delphi Survey Findings

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they were defined in a peer exchange workshop led with technical support from FHWA's scenario planning team. Each one is defined by external forces and documented assumptions, some of which include immigration, population growth, federal and state taxes, land use, climate outcomes, natural disasters, and technology. In their workshop, MCT focused on using language that would elicit variety in the possible proposed futures, rather than a normative vision or "goal future," by avoiding language such "what do you want the future to look like?" and instead asking for a story or a narrative of a possible future (even if it is one participants would not like to see come to fruition). Following the workshop, MCT used participant comments and surveys to consolidate 11 considered scenarios into the final three.

Communication of findings is a challenge that MTC has faced with the scenario planning approach. They have found that they need to be careful when presenting potential scenarios not to frame them as what they want to happen but rather what they think could possibly happen. It can also be politically challenging to discuss the driving forces behind scenarios and translating them to the Bay Area context, when many of them are based on assumptions about international, federal, and state action and policy that is outside of MTC's control.

MTC's ultimate goal with the Horizon scenario planning effort is to highlight issues and opportunities within each scenario so that they can propose suites of actions and strategies that would be most flexible and responsive to the diversity of futures that may be realized.

	Rising Tides, Falling Fortunes	Clean and Green	Back to the Future
Immigration and Trade	**Reduced** +20,000 Immigrants Annually	**Similar to Today** +80,000 Immigrants Annually	**Increased** +240,000 Immigrants Annually
National Growth	**Limited** +1.6% Annual Productivity +0.4% Annual U.S. Population	**Similar to Today** +2.8% Annual Productivity +0.7% Annual U.S. Population	**Rapid** +1.1% Annual U.S. Population +1.6% Annual Productivity
National Taxes and Funding	**Lower Funding** Due to Tax Cuts	**Higher Funding** Via Carbon Tax	**Similar to Today**
Land Use Preferences	**Housing More Urban** / **Similar to Today**	**Housing More Urban** / **Jobs More Dispersed**	**Housing More Dispersed** / **Jobs More Urban**
National Environmental Policy	**Relaxed Regulations** +3-feet Sea Level Rise 10% Electric Vehicles	**Stricter Regulations** +1-foot Sea Level Rise 95% Electric Vehicles	**Stricter Regulations** +2-foot Sea Level Rise 75% Electric Vehicles
New Technologies	**More Limited** 10% Autonomous Vehicles 10% Telecommute Share	**Widespread** 95% Autonomous Vehicles 30% Telecommute Share	**Widespread** 75% Autonomous Vehicles 15% Telecommute Share
Natural Disasters	**Earthquake** Magnitude 7.0 Hayward Fault	**Earthquake** Magnitude 7.0 Hayward Fault	**Earthquake** Magnitude 7.0 Hayward Fault
LEGEND	LOWER	SIMILAR TO TODAY	HIGHER

What if…new technologies and a national carbon tax enabled telecommuting and distributed job centers?

What if…the federal government cuts spending and reduces regulations, leaving decisions to states and regions?

What if…an economic boom and new transportation options spur a new wave of development?

Figure 8: The Three Futures and Their Driving Forces

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Delaware Valley Regional Planning Commission.
The DVRPC assembled an interdisciplinary task force called the Futures Group to design and assess scenarios for their latest scenario planning effort in Fall 2014. They down-selected from 17 future forces to five, asking Futures Group members to rate each by their impact and their likelihood; they called the final five the "Future Forces." For each Future Force, they guided discussion from the Futures Group by asking "What are the likely outcomes of this Future Force?"; "What action steps can the region take to accentuate the positive and to weaken the negative outcomes?"; and "What should be our regional transportation investment priorities based on this driving force?"

The second phase of these efforts integrated each of the five Future Forces into two modeling frameworks for 2045: one a socio-demographic systems dynamic model and the other a sketch-level travel demand model. These models produced projections in terms of demographics, greenhouse gas emissions, vehicles per capita, VMT, travel speeds, crash rates, transit trips, and annual household transportation costs. They also considered interactions between the two modeling frameworks, where outcomes ranged from both being strengthened, both being weakened, and mixed impacts.

Another best practice the DVRPC implemented was the identification of leading indicators that could be used to assess in the interim whether or not a Future Force is happening. These leading indicators are intended to help determine whether a force is occurring in the region and, if so, motivate the implementation of contingent regional actions, which were also developed for each scenario. Contingent regional actions are scenario-specific and designed to be most responsive to each individual force's likely outcomes.

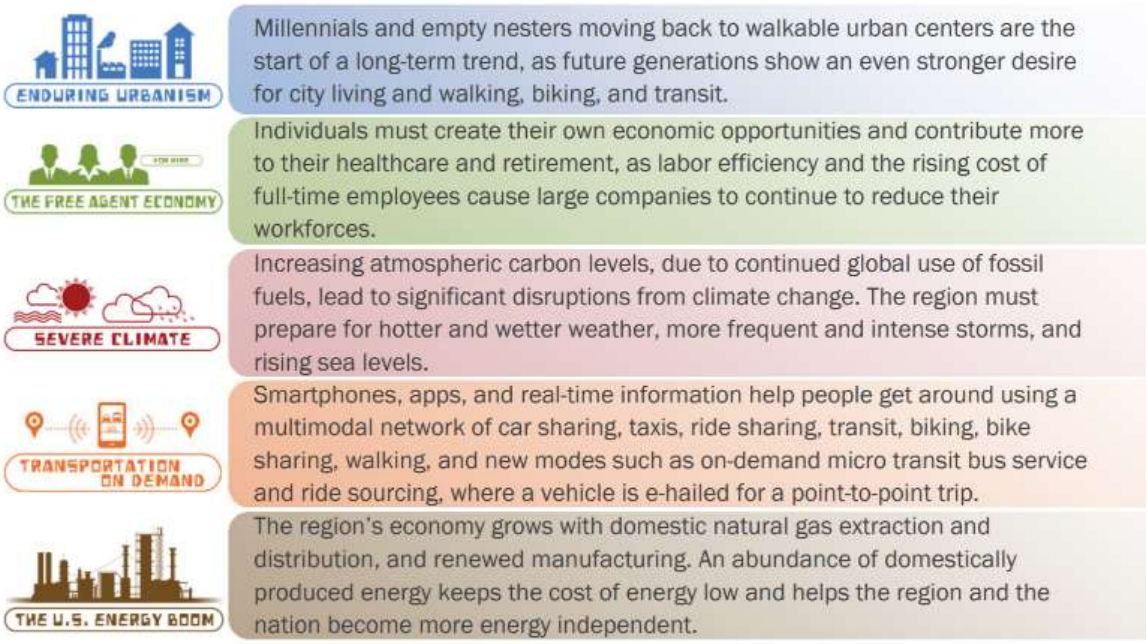

Figure 9: The Final Five Future Forces

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Table 1: Sample of Interactions Table

Force 1	Force 2	Relationship	Interactions Between Them
Enduring Urbanism (+)	The Free Agent Economy (+)	Strengthens Both	■ The Free Agent Economy may be a cause of Enduring Urbanism. Together, they may strengthen the region's agglomeration economy.
Enduring Urbanism (+)	Severe Climate (0)	Mixed Impacts	■ Severe Climate may reinforce Enduring Urbanism, though it could restrict development of desirable riverfront areas, and add risk to growing development centers. ■ Enduring Urbanism could reduce the risk of Severe Climate.
Enduring Urbanism (+)	Transportation on Demand (0)	Mixed Impacts	■ Transportation on Demand provides more travel options that do not require car ownership, which is being sought by some individuals interested in Enduring Urbanism lifestyles. ■ The ability to be car-free or car-lite in more suburban settings could weaken the desire for Enduring Urbanism. ■ Conversely, Enduring Urbanism preferences for walking and biking could reduce growth in Transportation on Demand.
Enduring Urbanism (-)	The U.S. Energy Boom (-)	Weakens Both	■ The U.S. Energy Boom could worsen air quality and environmental conditions, and low-cost energy generally encourages lower-density development. In sum, this potentially detracts individuals interested in Enduring Urbanism lifestyles, making it less likely to happen. ■ Ongoing weakness in the energy market combined with ongoing interest in living in walkable centers could strengthen regional movements against increasing regional energy distribution.

Table 2: Future Force Indicators

Future Force	Proposed Indicators
Enduring Urbanism	• Percentage of Population in Core Cities and Developed Communities • Percentage of Employment in Core Cities and Developed Communities • Percentage of Residential Building Permits in Core Cities and Developed Communities • Annual VMT Per Capita • Annual Transit Ridership Per Capita • Transit, Walking, and Biking Commute Mode Share
The Free Agent Economy	• Coworking and Shared Office Space • Percentage of Businesses with Four or Fewer Employees • Self-Employed Workers as a Percentage of All Population Over 16 Years Old • Unemployed Workers as a Percentage of Total Labor Pool • Percent of Households that Rent
Severe Climate	• Global Atmospheric CO2 (Parts per Million) • Average Regional Temperature and Days over 90 Degrees Fahrenheit • Average Regional Precipitation and Days with More than One Inch of Precipitation • Annual Regional Sea Level Change
Transportation On-Demand	• Regional Car Ownership per 1,000 Capita • Zero-Car Households • Non-Single Occupant Vehicle Commute Mode Share
The US Energy Boom	• Annual Natural Gas Exports from the Region • Regional Petrochemical Jobs

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Opportunities for Texas

In April 2017, the Association of Metropolitan Planning Organizations (AMPO) convened a Connected and Autonomous Vehicles Working Group to identify challenges, opportunities, and the current state of practice. Although the discussion focused on how MPOs can use scenario planning to initiate regional discussions around CAVs, the findings are relevant to state DOTs as well. The working group identified the five following key uncertainties, which have been adapted to encompass emerging technologies in general:

- What is the timeline for deployment?
- What are the safety implications?
- What are the capacity and congestion implications?
- What are the mobility and mode choice implications?
- What are the funding implications and roles of transportation agencies?[xii]

Texas can address each of these priority questions within a scenario planning framework that builds emerging technology considerations into each phase of outreach and implementation. Based on the scan of national, state, and regional scenario planning best practices that incorporate emerging technologies, Texas needs to build consensus around the approach to the following scenario planning steps.

1. Set an objective environment and a priority environment
2. Define driving forces
3. Down-select based on impact and likelihood
4. Project transportation system and societal outcomes
5. Identify indicators and policy/action suites

Based on lessons learned and recommendations given by the case study interviewees, the following section suggests questions and guiding principles Texas can consider adopting when implementing an exploratory, scenario-oriented approach to planning for emerging technologies.

- Keeping up to date on technology involved in connected vehicle (CV) implementation is of great importance, through continued research. The evolution of CV technology is in a state of constant change in abilities and regulation. By understanding these technologies earlier, establishing them in practice is made much easier.
- Establishing set goals as the outcome of CV technology implementation will assist in the structure and scope when creating and deploying a pilot program. Proper creation and understanding of goals will give a much more guided direction during decision-making.
- To encourage public support on CV pilot projects, better education needs to be provided on what the technology does, specifically how it differs from AV technology. The public needs to understand how this technology is beneficial to them, in order to obtain greater support.

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	Open Questions	Guiding Principles and Recommendations
Set an Objective and a Priority Environment	What planning and programming processes and Texas-specific environments should be explicitly incorporated into scenarios?	Long-haul and urban freight, rural communities, growing metropolitan areas or megaregions, and low-transit suburbs could be a few. **Texas needs to choose environments that represent the diverse needs across the state and that can be influenced or shaped by statewide policy and action. Each should be subject to technological impacts, and Texas should select relevant and explicit priority technologies to consider within these environments.**
Define Driving Forces	What are the greatest social, environmental, and political uncertainties that could shape the next decades in Texas?	Immigration policy, extreme drought and climate change, demographic shifts towards younger and more racially diverse populations, evolving energy markets that weaken the oil and gas industry, and localization of freight and logistics hubs could all be driving forces. **Texas must incorporate a realistic blend of possible driving forces, not relying only on optimistic ones or ones that are currently underway. Technology will be a major driving force.**
Down-select Scenarios	What mix of "likely" and "wildcard" scenarios should Texas focus on?	The mix here reflects how resilient to risk and diverse future outcomes Texas wants to be. Given the rapid rate of change that Texas is currently undergoing, **the future scenarios should be diverse in likelihood and desirability, so that strategies will be flexible and resilient. They should reflect of a range of technological development and adoption.**
Project Scenario Outcomes	What tools and methods will Texas use to evaluate the various scenarios?	Texas needs to define assumptions about demographics, economy, and policy; choose desired model outputs and measures; and choose a level of investment in modeling, ranging from sketch-level to a full travel demand model. **Texas must clearly document and justify assumptions and be cognizant of how these assumptions will bias the projected outcomes. Industry interviews and panels can inform the assumptions made about technology adoption timelines and transportation system impacts.**
Identify Indicators and Actions	What interim statistics should Texas monitor and what policies or investments should be considered?	The breadth of possible actions depends on which stakeholders and state agencies Texas wants to involve in transportation-related policy and action. **Texas should identify and engage state agencies and organizations with existing or emerging roles in transportation governance, such as the Departments of Public Safety, Insurance, and Motor Vehicles; Commission on Environmental Quality; the Comptroller; the Governor; and the Legislature.**

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Planning for an Uncertain Future

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