St. Louis Region Emerging Transportation Technology Strategic Plan

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Prepared for

East-West Gateway Council of Governments

by

ICF

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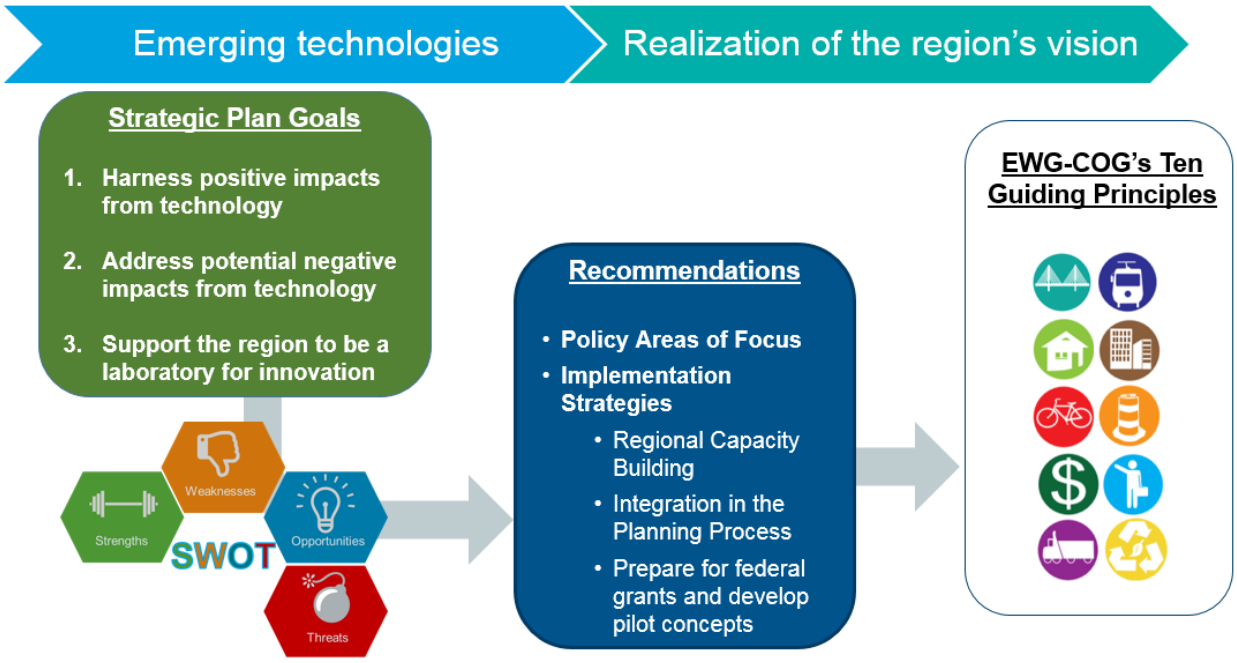
EXECUTIVE SUMMARY

This Emerging Transportation Technology Strategic Plan was developed in response to the rapidly advancing technologies that are already disrupting the transportation industry and challenging policymakers involved in transportation planning and investment decision making. The advent of connected vehicles and infrastructure that use sensors to assess real-time conditions and communicate with each other, an explosion of data and advanced analytics, new on-demand mobility options, eco-friendly vehicles and infrastructure, and other advancements offer the potential to dramatically improve the safety, reliability, accessibility, and environmental footprint of our transportation networks. At the same time, these technologies may significantly affect travel demands and modes used by passengers and freight, land use patterns, and future transportation investment needs in ways that are not fully understood. In addition to the likelihood of improved performance, there are possible unintended or adverse consequences that transportation planners and policy makers may need to confront.

Recognizing these challenges, this Strategic Plan is designed to help the East-West Gateway Council of Governments (EWG) to better position itself to prepare for emerging transportation technologies in its planning and investment decision making processes.

As shown in Figure ES-1, the plan lays out three major components: 1) strategic goals; 2) an analysis of Strengths-Weaknesses-Opportunities-Threats; and 3) recommendations related to policy areas of focus and implementation strategies to support positive outcomes for the region.

Figure ES-1: Components of the Strategic Plan



The information used as the basis for developing this document included: 1) a robust literature review to identify emerging technology trends, regional conditions, and experience of other regions in integrating emerging technologies into the transportation planning process; 2) a regional stakeholder survey to gather input on their state of knowledge, and planning in relation to emerging transportation technologies, as well

as perspectives on regional strengths and weaknesses; and 3) a series of expert interviews with 15 thought leaders from academia and the public and private sectors to gain perspectives on emerging transportation technology.

Strategic Plan Goals

The guiding direction of this Emerging Transportation Technology Strategic Plan is to support the region in achieving its ten Guiding Principles, which have been articulated as priorities to guide the region's planning and policy:

- Preserve and Maintain the Existing System
- Support Public Transportation
- Support Neighborhoods & Communities
- Foster a Vibrant Downtown & Central Core
- Provide More Transportation Choices
- Promote Safety and Security
- Support a Diverse Economy with a Reliable System
- Support Quality Job Development
- Strengthen Intermodal Connections
- Protect Air Quality and Environmental Assets

The Plan lays out three strategic goals in relation to emerging transportation technology:

1. **Harness positive impacts from technology** – Foster and deploy emerging transportation technologies that help advance the region's vision and Guiding Principles through policies, plans, and strategic investments.
2. **Address potential negative impacts from technology** – Consider the risks of emerging transportation technologies in the region's planning and investment decision making to help mitigate potential adverse consequences on the region and its residents.
3. **Support the region to be a laboratory for innovation** – Bring innovation to the region through application of emerging transportation technologies that support economic growth and quality jobs.

Strengths-Weaknesses-Opportunities-Threats Analysis

The Strategic Plan utilized a Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis to determine key areas of focus for the region, taking into account the broad opportunities and threats that might arise from new technologies, as well as regional strengths and weaknesses associated with the application of emerging transportation technologies. The result from the SWOT analysis is summarized in Table ES-1.

Table ES-1. SWOT Analysis.

	To Leverage	To Overcome
Internal	**S**trengths • Multi-modal transportation system • Major freight hub • Mid-size region, potentially well geared toward pilot testing • Intelligent transportation systems (ITS) infrastructure • Interest from stakeholders	**W**eaknesses • Fragmented and complex government structure, across two states and multiple local governments • Population decline in urban core • Social barriers, including perceptions of inner-city crime • Sprawling region with low density and heavily car-centric travel patterns • Funding constraints
External	**O**pportunities • Potential positive technology impacts: - Significant safety improvements - Reduced travel costs - Increased travel choices - Improved access, particularly for those currently with limited mobility and those without access to private vehicles - Improved system reliability - Possible transit service improvements and reduction in cost - Optimized supply chain, yielding economic benefits - Quality job development in emerging technology fields - Air pollutant and greenhouse gas reductions - Potential for clean energy generation • Federal grant programs • Private sector funding	**T**hreats • Potential adverse technology impacts: - Reduced funds from traditional transportation funding sources - Increases in vehicle travel and congestion - Increases in sprawl / decentralized development patterns - New options draw people off of public transit - Gaps in access by those who cannot afford - Cyber-security threats associated with new technology - Reduction in employment, as jobs related to driving could be displaced

Drawing upon the regional SWOT analysis and research on the ongoing and expected impacts of technologies more generally, expected impacts of technology on each of the region's Guiding Principles were identified. Given the uncertainty associated with many technologies, impacts were considered on the basis of both their certainty and the degree to which they would have a positive or negative impact on advancing the regional goals (Figure ES-2).

Figure ES-2: Estimated Impacts of Transportation Technologies on EWG's Guiding Principles

This analysis revealed that emerging transportation technology is likely to have many positive impacts and create positive opportunities for utilizing technology to support regional goals – most notably on safety, environmental quality, intermodal connections, transportation choices, and reliability – but also creates some threats of negative impacts. For instance, technology could support public transportation through automation and providing more seamless on-demand connections to fixed route services; yet at the same time, new on-demand services could attract riders away from traditional public transportation. While market forces and advances in technology that are currently unknown will play a critical role in these impacts, public policy is likely to have an important role. In addition, technology will likely have implications for transportation investment needs and funding. For instance, through more efficient routing, shorter travel distances between vehicles, and potential for higher speeds, automation may squeeze more vehicle capacity out of existing highway infrastructure, reducing the need for new capacity to address congestion. Impacts on investment needs should be considered as part of long-range transportation planning.

Recommendations

Based upon the SWOT analysis and the expected and uncertain impacts of technology, this Strategic Plan recommends several areas of policy focus directly linked to the region's Guiding Principles:

- **Safety** – Advancing deployment of safety innovations.
- **Security** – Ensuring data privacy and cybersecurity.

- **Urban Form and Public Transit** – Fostering policies that address the threats of increased decentralization due to technology and harness the advantages to support a vibrant central core and the success of public transportation.
- **Reliability** – Using technology to improve access to real-time traveler information and optimize system reliability.
- **Equity** – Using technology to enhance connections for underserved communities and ensuring that technology-based services don't bypass disadvantaged communities.
- **Freight and Logistics** – Using technology to enhance efficient goods movement and spur economic development.
- **Infrastructure Preservation and Maintenance** – Applying technology to improve the monitoring of infrastructure conditions and strengthen transportation asset management.
- **Funding** – Addressing the challenge of technology exacerbating the problem of limited revenues for transportation investment and maintenance.
- **Environmental Quality** – Advancing the adoption of eco-friendly infrastructure and vehicles.

Based on these results, the Strategic Plan provides recommendations for EWG to integrate emerging transportation technology into its planning activities, with a focus on improving institutional readiness, changes in the planning processes, and initiating pilot projects. Recommendations are highlighted in relation to the roles and responsibilities of EWG:

- **Data Modeling and Analytics**
  - Bolster staff data analytics capabilities,
  - Develop a robust data collection plan, leveraging new forms of data to support performance measures, and
  - Enhance modeling to address emerging transportation technologies.
- **Long-Range Planning**
  - Establish a Technology Advisory Committee,
  - Develop a shared vision for technology to recommend regional strategies,
  - Conduct scenario planning to better understand alternative futures and to support more informed analyses of investment priorities,
  - Include considerations related to emerging transportation technology as a factor when prioritizing projects for the regional transportation plan (RTP),
  - Update the regional ITS Architecture and Deployment Plan, and
  - Update the Congestion Management Process and ensure that other regional planning products integrate emerging transportation technology.
- **Programming and Funding** – Update the current Transportation Improvement Process (TIP) project selection process to encourage innovative technology applications.
- **Pilot Program Development**
  - Build federal grant readiness by creating a compelling grant narrative,
  - Establish a grant tracking system, and
  - Develop and fund a regional technology deployment pilot program.
- **Education, Convening, and Supporting Partner Efforts**
  - Work with local universities to identify opportunities to collaborate,
  - Coordinate peer-to-peer workshops and facilitate regional discussions on topics including public-private partnerships, changes to procurement policies, and data collection and analytics,
  - Conduct assessments of local governments' awareness and readiness regarding technology on a periodic basis.

If implemented, these activities will help to support the St. Louis Region in maximizing the benefits and reducing the risks of new technology, support innovation, and help the region to achieve regional goals.

1. MOTIVATION AND BACKGROUND

Motivation

Why develop an Emerging Transportation Technologies Strategic Plan?

Society today is in the midst of a technological revolution that is likely to fundamentally change the way in which people live, work and relate to one another. This new wave of technology deployment goes beyond the digital revolution that started in the middle of the 20th Century, and is characterized by a fusion of technologies built on the Internet of Things, and breakthroughs in artificial intelligence, robotics, and quantum computing that are blurring the lines between the physical, digital, and biological spheres.[1] While these technological leaps are rapidly changing many aspects of society, they are having particularly important impacts through innovations in transportation. Emerging transportation technologies, such as connected vehicles and infrastructure, new shared mobility options, autonomous vehicles, and drones are ushering in a new era of transportation that may fundamentally affect the way people travel and deliver goods and services.

The St. Louis region has identified ten Guiding Principles to support the region's future growth and prosperity, and emerging technologies may have significant impacts on desired outcomes in relation to these principles. Technology advancements have already been creating disruption in traditional transportation business models, and are likely to have dramatic impacts on safety, mobility, and system performance over the next 20 to 30 years. Moreover, the pace of broad technology adoption has been quickening over time.

Emerging transportation technologies go well beyond the Intelligent Transportation System (ITS) investments that have been implemented in the past, and present significant new opportunities to address previously unsolvable problems. But these technologies also present new challenges, and as technologies continue to advance, governments will need to understand and mitigate risks. Recognizing the importance of these issues, the East-West Gateway Council of Governments (EWG) has developed this Emerging Transportation Technology Strategic Plan (Strategic Plan henceforth) in order to better prepare for future transportation technologies in its regional transportation policy and investment planning. This Strategic Plan provides context on emerging transportation technologies, potential impacts on region goals, and recommendations for EWG that can be used to shape its regional planning activities.

Plan Structure

This Strategic Plan is organized into the following sections:

[1] Schwab, Klaus. 2016. *The Fourth Industrial Revolution: what is means, how to respond*. World Economic Forum. Available at: https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

Looking to the Future	**Section 2: Emerging Transportation Technology Trends** identifies types of emerging transportation technologies in development that are likely to advance over the coming years.
	Section 3: Strategic Goals describes the region's Guiding Principles and this Plan's goals in relation to emerging transportation technology.
Strengths-Weaknesses-Opportunities-Threats	**Section 4: Development of the Strategy** discusses the process for developing recommendations, including the overall results of a Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis.
	Section 5: Assessing the St. Louis Region's Readiness to Deploy Emerging Technologies provides more information on the assessment of regional strengths and weaknesses.
	Section 6: Implications of Emerging Transportation Technologies discusses key opportunities and threats to the region from transportation technology, as well as impacts on transportation investments.
Recommendations	**Section 7: Policy Areas of Focus in Regional Planning and Investment Decision Making** highlights policy areas recommended for focused attention in long-range planning, along with potential policies and strategies which should be considered in the next update to the region's long range transportation plan.
	Section 8: Recommendations: Moving Forward from Strategy to Implementation provides recommendations for fostering deployment of technologies and integrating technology considerations into the regional planning process. These recommendations are arranged according to the roles that EWG plays, and will help position the region to effectively identify, analyze, and implement investments in new technologies.

2. EMERGING TRANSPORTATION TECHNOLOGY TRENDS

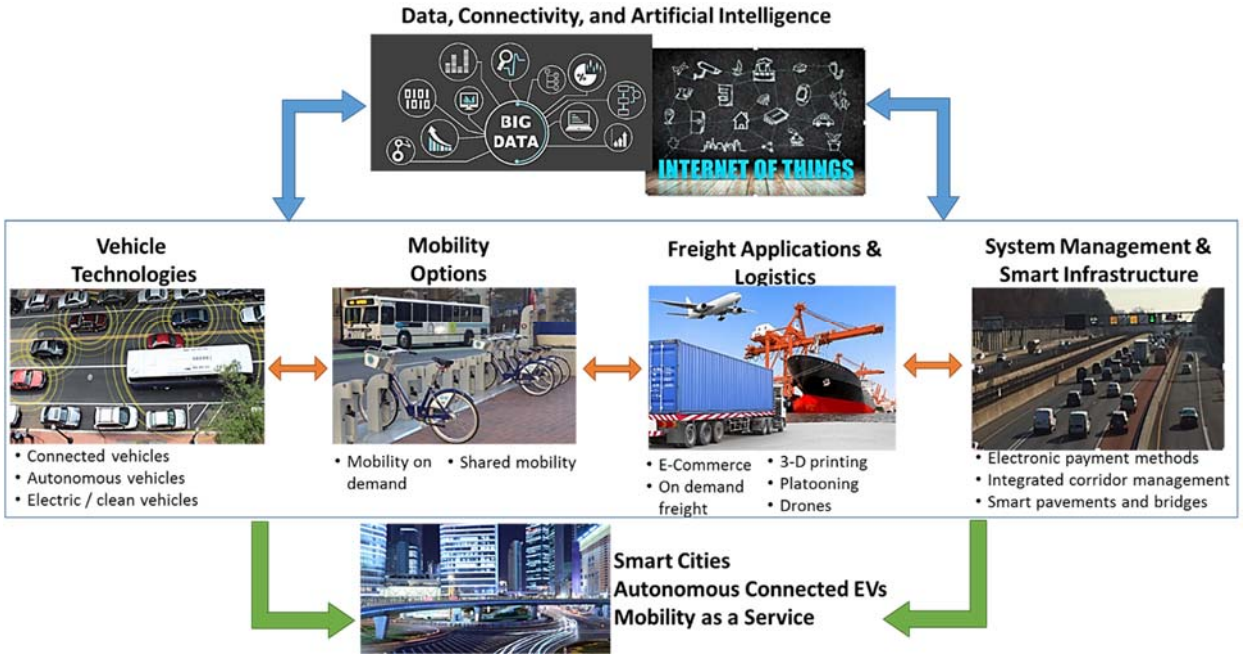
The East-West Gateway's current long-range transportation plan, Connected 2045, recognizes the importance of emerging transportation technologies in planning for the future of the St. Louis region. It provides context on the history of transportation in the region, and highlights the promise of future technologies—from vehicles that can drive themselves to advances in infrastructure technology such as pavements that can repair themselves, melt snow, and adjust their lane striping.

What are emerging trends in transportation technology?

Overarching Technology Trends

As a starting point for developing this Strategic Plan, it was important to explore what types of emerging transportation technologies are in development and likely to advance over the coming years. While the future is uncertain, several interconnected trends are likely to play a pivotal role in the future of transportation, as shown in Figure 1. This section draws in part of a research scan on this topic conducted by ICF in late 2016 for the Atlanta Regional Commission, as well as a previous study for the Federal Highway Administration on Emerging Transportation Technologies in 2015, and recent work conducted by the Eno Center for Transportation, and supplemented by recent reports, news articles, and papers. It describes and defines the technologies, some of which are new to market, or still in testing, and also explains their significance to transportation planners at a high level.

Figure 1. Transportation Technology Trends (Source: ICF).



Big Data, Connectivity, and Artificial Intelligence

The ability to connect to other devices, to be able to send and receive data, is a basis for many of the technology advancements in transportation happening today and likely to accelerate in the future. The importance of (big) data will continue to increase as the Internet of Things (IoT) expands and more objects

gain connection to the internet. It is expected that over 50 billion devices will be connected by 2020,[2] including vehicles, wearable technology and house appliances.

While ubiquitous connected devices drive the tremendous growth in data collection, these data would be of much more limited use without the parallel developments in communications, data storage, computer memory, and data processing. Data then can become actionable information. Significant advances in machine learning thrive in the ocean of data that is now available, to create *training datasets*, which can be used to generate predictions or *feature extraction*, that is to extract previously hidden information about patterns and associations relating to human behavior, the physical environment, and their interactions.

Most of us were first exposed to machine learning through *recommender systems*, such as those used in Amazon and Netflix to "predict" with products or movies would be of interest to us based on training datasets with data on our purchase history, browsing history, and other unstructured data our personal characteristics. For transportation applications, we see variants of recommender systems, for example navigation systems. These applications will only grow and become more accurate with the growth of training datasets. Development and application has been more intense around certain types of machine learning algorithms—including for example deep learning—but a discussion if these would fall outside of the interest of this report.

Machine learning is one part of the broader technology space of artificial intelligence, or AI, which refers to systems that can perform tasks involving cognitive functions similar to those of humans. AI applications are at the heart of some of the more important technology trends affecting transportation, including vehicle automation. Indeed, AI algorithms open the possibility that automated cars be less dependent on preloaded detailed maps of their routes, and more reliant on the vehicle's own intelligence to understand its environment.[3]

For transportation specifically, such a trend is enabling many advances in vehicles, as well as transportation services (transit), and system planning and operations. Increased access to detailed data is allowing planners and system operators, as well as the public, to better understand the time and location of congestion, and its potential causes. Furthermore, it enables a more efficient system for freight delivery. For instance, the private sector company Under Armour® currently uses information collected regarding the workout habits, product preferences, and buying history of more than 140 million individuals to provide faster deliveries of products and optimizing its supply chain to meet consumer demand in the moment.[4]

Beyond operations, big data is also an important asset for planning as it can be used to better understand travel behavior. The City of Boston has partnered with the Transportation Network Company (TNC) Uber, with Uber providing aggregated information on customers, including trip origin, destination, departure time, distance, and duration, which planners believe will be helpful for informing travel needs. Many cities and State DOTs have also entered a two-way partnership with Waze to share information about current traffic conditions and events (e.g., incidents and work zone locations).

Connectivity also has the potential to significantly influence travel demands for both passengers and freight, such as through telecommuting, telemedicine and e-commerce. For instance, telecommuting has gained

[2] MIT Technology Review. "MIT Technology Review Business Report: The Internet of Things." July/August 2014. http://www.technologyreview.com/businessreport/the-internet-of-things/download/

[3] Gibney, Elizabeth. 2016. Google masters Go: Deep-learning software excels at complex ancient board game. *Nature* 529:445-446. *Available at:* http://www.nature.com/polopoly_fs/1.19234!/menu/main/topColumns/topLeftColumn/pdf/529445a.pdf

[4] Lori Mitchell-Keller. 2016. How Under Armour Used Digital Experiences to Shift Business Model. Retrieved from: http://multichannelmerchant.com/lists/armour-used-digital-experiences-shift-business-models-13052016/

significant ground in recent years, mainly due to improvements in broadband and communication technologies. This enables people to 'plug in' from anywhere and perform their jobs outside of the office space. As such, they can work from home or any location that provides them an internet connection. Research indicates that half of the American workforce has a job that is conducive to telecommute, while approximately a quarter of the American workforce telecommute at some frequency.5 Similar to telecommuting, enhanced telecommunication technologies are allowing medical staff to provide clinical health care, regardless of their location. These technologies permit communications with patients, as well as the transmission of medical, imaging and health informatics data from one site to another. Several companies have started to provide these services within the US, such as Teladoc, American Well, and Doctor on Demand.

Over the past several years, the commercial and retail industries have made significant leaps in e-commerce. One of the most noticeable example of the latter is Amazon, which has positioned itself as a leading promoter of e-commerce by providing range of services, including:

- Amazon Prime Now that provides same day delivery
- Amazon Dash button that allows a consumer to order products as they run short (e.g., get their laundry detergent as it runs low, rather than part of a large grocery order)
- Amazon Pantry that allows the consumer to buy non-perishable products at a discount price by grouping them into a single box
- Amazon's mobile application that enables consumers to buy any available product anytime and anywhere

E-commerce has risen from about 3.5 percent of total retail sales in 2007 to 8.3 percent by the end of 2016.[6] The market is being driven by shoppers making purchases on mobile devices, which is rapidly reshaping the logistics of the retail industry.

Advanced Vehicle Technologies

Technologies used in transportation—including passenger vehicles, transit vehicles, and freight trucks—are advancing rapidly and are expected to result in significant changes in how vehicles are operated over the coming decades, with potentially very significant implications on transportation safety and mobility, as well as on transportation service delivery, infrastructure needs and land use patterns. Advancements in vehicle technologies can be grouped into three major categories: autonomous vehicles, connected vehicles, and electric and alternative fueled vehicles.

Connected Vehicles (CVs)

Enhanced communication technology is enabling vehicles to communicate with each other (vehicle-to-vehicle or V2V) and with infrastructure (vehicle-to-infrastructure or V2I) such as traffic signals and roadway devices that collect and transmit information.[7] This is enabling a plethora of new advances in communication at different levels within the transportation network. For instance, INRIX's OpenCar[8] offers a suite of in-vehicle software and driving optimized content. This software receives real-time parking information of monitored parking infrastructure and allows you to reserve a space if desired. The OpenCar

[5] Global Workplace Analytics. 2016. "Latest Telecommuting Statistics." Retrieved from: http://globalworkplaceanalytics.com/telecommuting-statistics
[6] U.S. Census Bureau. 2017. "Quarterly Retail E-Commerce Sales: 4th Quarter 2016." Retrieved from: https://www.census.gov/retail/mrts/www/data/pdf/ec_current.pdf
[7] Intelligent Transportation Systems Joint Program Office, Connected Vehicle Research website, *Available at:* http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.htm
[8] INRIX OpenCar website, *Available at:* http://inrix.com/products/inrix-opencar/

software is also looking to integrate Amazon's Alexa, enabling equipped vehicles to "access a host of services from within their vehicle via Alexa, including Amazon Music, Audible audiobooks, and INRIX Driver Services such as traffic, parking, incidents and road weather conditions." This will also allow drivers to send information to their vehicle while at home via products like Amazon Echo or Echo Dot.

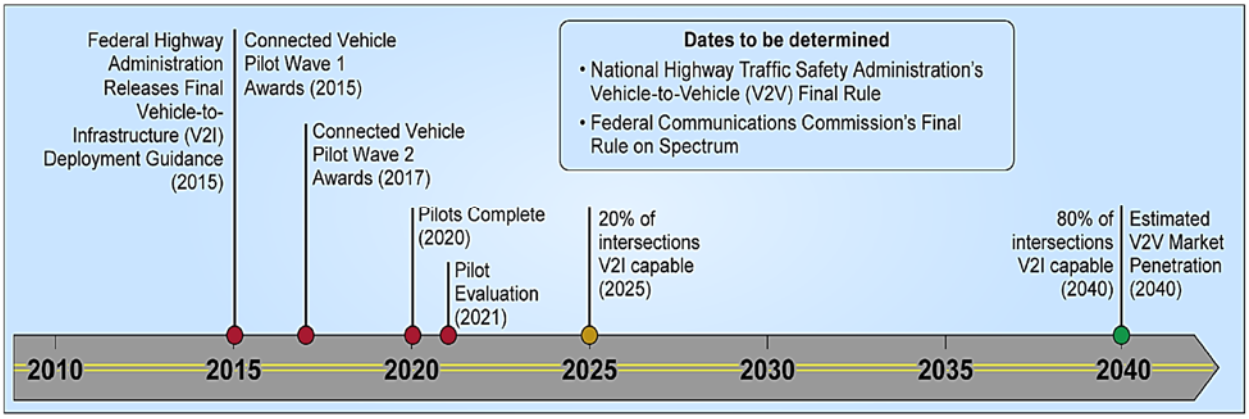
Different communication technology protocols have been and are being developed to allow/enhance connectivity within the realm of transportation. From a vehicle perspective, four technologies lead the market in terms of availability and readiness:

- Cellular – broadband solutions currently available are migrating to 4G/LTE (available now) and eventually 5G (available in 2020). Lightweight versions of connectivity are already available and being upgraded (such as 3G on vehicles).
- Wi-Fi – already broadly deployed and will continue to evolve with medium range communication. Wi-Fi___33 is an excellent alternative for connectivity in dense areas, as there are various protocols for Wi-Fi with low power consumption.
- Bluetooth – another connectivity alternative which consumes low energy and it able to transmit data over short distances (roughly up to 10 meters).
- Satellite – a very effective broadcast mode that can be used to provide back-up communication capability, closing the gap in coverage by other networks.

Other communication technologies are being explored. For instance, the U.S. Department of Transportation (U.S. DOT) is advancing the use of Dedicated Short Range Communication (DSRC). This is being deployed in both passenger and freight vehicles as part of the Connected Vehicle Pilot Program. In September 2016, U.S. DOT awarded three cooperative agreements collectively worth more than $45 million to initiate a Design/Build/Test phase of the *Connected Vehicle Pilot Deployment Program* in three sites: Wyoming, New York City (NYC), and Tampa.[9] While New York and Tampa mainly focus on passenger vehicles, the Wyoming Pilot is has a strong freight focus. Wyoming DOT expects to equip nearly 400 trucks with on-board units and install around 75 roadside units to enable V2V and V2I communication along Interstate 80 by Fall/Winter 2017. CV technology will optimize freight by enabling new modes of operation, such as truck platooning, efficiency-improving automated manual transmissions, and service features like the ability to control a tractor from outside the cab with a tablet for difficult parking scenarios—all of which are expected to be available in the near future. Certain voluntary systems such as vehicle platooning will likely be first to arrive to market since they do not require high adoption rates to be effective, unlike some V2V applications.[10] An expected timeline for V2V and V2I deployment from the U.S. Government Accountability Office (GAO) is summarized in Figure 2. The GAO estimates high levels of V2V and V2I deployment by 2040 contingent upon certain intervening steps being successful.[11]

[9] ITS Joint Program Office. 2016. "Connected Vehicle Pilot Deployment Program." http://www.its.dot.gov/pilots/
[10] Underwood, Steven. 2016. Automated, Connected, and Electric Vehicle Systems Expert Forcast and Roadmap for Sustainable Transportation. http://graham.umich.edu/media/files/LC-IA-ACE-Roadmap-Expert-Forecast-Underwood.pdf
[11] GAO. 2015. Vehicle-to-Infrastructure Technologies Expected to Offer Benefits, but Deployment Challenges Exist. GAO-15-775. http://www.gao.gov/products/GAO-15-775

Figure 2. U.S. DOT's Planned CV Path to Deployment 2010-2040



Source: GAO, 2015

Many other protocols are emerging to transfer data, each can be tailored to satisfy specific needs. A noteworthy emerging technology is the SigFox network (https://www.sigfox.com/), a long-range low-data connectivity tech for relaying information which demands really low power. So far it has mainly been used in Europe, but is making its way into the U.S. It is characterized by ultra-low power and long range (over 1-2 km) and a low quantity of data. It could be an excellent fit for low-density rural areas.

The impact of CV is examined in the "National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Scenarios," as part of the National Connected Vehicle Field Infrastructure Footprint Analysis[12]. This document presents multiple scenarios of usage of connected vehicle technologies, including the deployment of vehicle and back-office applications and systems. Specifically, the document examines the following deployment scenarios:

1. Urban Deployments – mainly impacting safety (particularly intersection safety and incident/emergency response) and congestion mitigation.
2. Rural Deployments – primarily improving safety, through increased awareness, and at secondary stage, the mitigation of localized congestion.
3. Multi-state Corridors – with primary objective being enhanced response to major incidents and events, such as natural disasters) and congestion mitigation.
4. DOT System Operations and Maintenance – facilitating operational improvements in both gathering operations data and providing data back to maintenance personnel.
5. Commercial Vehicle and Freight Systems - enabling more efficient demand management and operations by providing targeted information to truckers, carriers, and shippers at ports and on the road.
6. International Land and Border Crossings – enabling more efficient demand management and operations by providing targeted information to truckers, carriers, and shippers at border crossings.
7. Fee Payments – potentially reducing operation and maintenance cost of existing and new toll facilities, providing effective and secure revenue collection, and supporting other operating objectives such as monitoring vehicle eligibility on high occupancy facilities.

[12] Jim Wright, Christopher J. Hill, J. Kyle Garrett, and Rajat Rajbhandari. 2013. "National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Scenarios." American Association of State Highway and Transportation Officials (AASHTO), Washington, D.C.

Autonomous Vehicles (AVs)

Fully and semi-autonomous features facilitate vehicles to operate without or with limited human interaction. The U.S. Department of Transportation (U.S. DOT) defines AV following SAE International's six levels of automation for on-road motor vehicles[13] in its "Federal Automated Vehicles Policy." In general, the levels and definitions include:

- **Level 0 – No Automation**: The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems
- **Level 1 – Driver Assistance**: The driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task
- **Level 2 – Partial Automation**: The driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task
- **Level 3 – Conditional Automation**: The driving mode-specific performance by an Automated Driving System of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene
- **Level 4 – High Automation**: The driving mode-specific performance by an Automated Driving System of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene
- **Level 5 – Full Automation**: The full-time performance by an Automated Driving System of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver

This technology is mainly driven by the significant advancement in sensors, cameras, radars, and communications technologies that are being installed in vehicles. Such advancements have shifted the discussion surrounding AV technologies from if high levels of automation will occur to when implementation will take place. Companies have already started developing and deploying vehicles with Levels 3 and up AVs that can navigate certain types of roadways and environmental contexts with almost no direct human input. Researchers at Carnegie Mellon University (CMU) have been working on self-driving cars since the mid-2000s. In September 2013, a CMU outfitted Cadillac SRX drove itself 33 miles to Pittsburgh International Airport, navigating suburban highways and two interstates; the car navigated exit ramps, changed lanes, and detected and reacted to pedestrians and bicyclists.[14] Google's self-driving cars have driven over 1.5 million miles, and have been tested in different cities, such as Mountain View, California; Austin, Texas; Kirkland, Washington; and metro Phoenix, Arizona.[15] Tesla motors has hinted that all new Model S will include autonomous features. However, a May 2016 fatal crash where a driver was using Tesla's autopilot mode has led NHTSA to open an investigation on Tesla's automated driving systems.[16]

As previously mentioned, this technology is also being developed for freight purposes. In May of 2015, Daimler Trucks was granted a road license for a self-driving heavy-duty truck. While still in its pilot phase, the implications of Daimler's *Freightliner Inspiration* are significant and provide many of the same

[13] SAE J3016™: Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems.
[14] Consumer Electronics Association, "Driverless Cars on the Rise." 2014. Retrieved from: http://www.ce.org/i3/Features/2014/January-February/Driverless-Cars-on-the-Rise
[15] Google, Self-Driving Car Project, http://www.google.com/selfdrivingcar/, accessed on August 4, 2016.
[16] Dan Hull, Jeff Plungis, and David Welch. 2016. "Regulators Open Investigation into Fatal Crash in Tesla Autopilot." Bloomberg Technology. http://www.bloomberg.com/news/articles/2016-06-30/nhtsa-opens-investigation-into-fatal-crash-in-tesla-on-autopilot.

advantages as autonomous cars.[17] In October 2016, OTTO, an Uber-owned AV trucking operation, completed a 120 mile commercial trip on Interstate 25 to deliver a beer load to an Anheuser-Busch InBev warehouse in Colorado Spring, CO.[18] Additionally, other features are emerging in the market, such as "advances in telematics, platooning software, efficiency-improving automated manual transmissions, and service features like the ability to control a tractor from outside the cab with a tablet for difficult parking scenarios."[19]

Automation is also becoming an area of increasing interest in the transit industry. Although automated guideway transit has primarily been used in applications such as airports, this type of system can be applied in more complex mass transit systems, and there are opportunities for automated buses that do not operate on a fixed guideway.

It is expected that AV technology will positively impact many aspects of transportation, specifically safety and mobility. However, there is still no consensus on how it will impact other aspects, such as vehicle miles traveled and vehicle ownership. Furthermore, as AVs gains ground in the market, traditional forms of transportation, including transit, may shift to allow for a new service-oriented model (e.g., AV taxis and buses). As such, infrastructure investments and operational improvements, travel choices and parking needs, land use patterns, and trucking and other activities may also be affected.

Electric and Alternative Fueled Vehicles (E/AFV)

Vehicle electrification is one of the key technology trends in transportation, and it is believed to be intimately related to vehicle automation and car sharing. The key regulatory push behind vehicle electrification has been the California Zero Emission Vehicle program, initiated in 1990. The recent reemergence of commercial electric models was initiated with the EV Project during the American Recovery and Reinvestment Act of 2009. However, the technology behind the early market entrants, such as the Nissan Leaf and the Chevy Volt, was not developed overnight. It was over a decade of research, development, and testing that resulted in technologies far superior to the models commercialized in the 1990s. Thanks to that long term commitment to technology development, their commercialization on a large scale was possible, when the US was hit by unprecedented spikes in oil prices. It was then shown that the diversification of the transportation fuel portfolio would not only benefit the environment, but would also be good for consumers and the economy.

Governments, municipal, state, and/or federal, will continue supporting the market uptake of electric vehicles. While the future of regulatory programs at the federal level seems uncertain, states and cities are poised to continue their support. For example, a coalition of 30 cities from across the US has announced that it intends to do a joint procurement of about 114,000 electric vehicles, with an investment of up to $10 billion. The U.S. Department of Energy's (DOE) EV Everywhere program, for example, aims to increase the use of plug-in EVs, making them "as affordable and convenience for the American family as gasoline-powered vehicles by 2022."[20] Furthermore, California's SB 1275 lays out a plan to put one million electric vehicles on the state's roads within 10 years to help California meet their greenhouse gas (GHG) emissions

[17] Glass, Dan. 2014. "A Complete Guide to the Future of U.S. Freight Movement." The Atlantic CITYLAB. Retrieved from http://www.citylab.com/work/2014/10/a-complete-guide-to-the-future-of-us-freight-movement/381012/.
[18] Mike Issac. 2016. "Self-Driving Truck's First Mission: A 120-Mile Beer Run." Retrieved from: https://www.nytimes.com/2016/10/26/technology/self-driving-trucks-first-mission-a-beer-run.html
[19] Glass, Dan. 2014. A Complete Guide to the Future of U.S. Freight Movement. CityLab. Oct 2, 2014. Retrieved from: http://www.citylab.com/work/2014/10/a-complete-guide-to-the-future-of-us-freight-movement/381012/
[20] U.S. Department of Energy. 2016. "About EV Everywhere." U.S. Department of Energy. Retrieved from http://energy.gov/eere/eveverywhere/about-ev-everywhere.

reduction targets. The bill creates credit enhancements to help families, includes income-based incentives for low- and moderate-income families to scrap their older vehicles, pilots Carsharing programs in areas with a lack of transit, builds more charging stations at multi-unit dwellings, and continues the purchase and leasing rebate program.[21]

In August 2016, Tesla Motors finalized a deal to purchase SolarCity Corporation, a full-service solar provider in the United States, a move that will make Tesla Motors "a unique combination of solar, power storage, and transportation," and the only integrated sustainable energy company in the world.[22] Under Musk's vision for the two companies, Tesla batteries would be used to store the energy that SolarCity's solar panels collect.

By 2018, the vehicle market expects to host several new "affordable" (i.e., equal or less than USD $35,000) and long range (i.e., around 200 miles) EV models. The high-profile entrants in this market include Chevy's Bolt, Nissan's Leaf, and Tesla's Model 3. These new generation of EVs will help promote alternate-fueled vehicles and significantly increase EV market share—potentially leading to stronger support for better and more inclusive policies regarding EVs, such as those related to electrified roadways.[23]

A National Research Council report suggested that an 80 percent reduction in light-duty vehicle greenhouse gas emissions by 2050 would be extremely difficult to attain and that vehicle electrification has to play a central role in a strategy toward deep carbon emission reductions. [24] Electric vehicles and fuel cell electric vehicles (FCEV) are zero emission platforms, but their deployment has to be accompanied with a strategy to reduce the carbon intensity of electricity generation.[25] FCEV use hydrogen as a fuel, which is turned into electricity onboard to provide power. Hydrogen can be produced in several ways; the two leading production pathways are methane (essentially natural gas) reforming and water electrolysis. The latter has the potential to result in carbon-free hydrogen if the electricity used in the electrolyzer is renewable (e.g. from solar).

The widespread market uptake of alternative fuels in general and zero emission vehicles in particular will need to meet the challenge of consumer acceptance. But this is only part of the picture. The magnitude of the transition involved requires to take a systems perspective, that take into account market as well as institutional forces. Studies show that the legitimation of zero emission vehicles among consumers is still in the early stage, there are also a host institutional factors that still favor the incumbent technologies.[26]

However, it noted that widespread consumer acceptance of alternative vehicles and fuels faces barriers, including the high initial purchase cost of the vehicles and the perception that such vehicles offer less utility and convenience than conventional internal combustion engine vehicles, as well as a limited refueling infrastructure for some alternative fuels. A study sponsored by the National Renewable Energy

[21] Sustainable San Mateo. Retrieved from: http://www.sustainablesanmateo.org/home/indicators-report/key-indicator/future-transportation-trends/. Accessed on August 7, 2016.
[22] Ramsey, Mike and Cassandra Sweet. 2016. "Tesla and SolarCity Agree to $2.6 Billion Deal." *The Wall Street Journal.* Retrieved from: http://www.wsj.com/articles/tesla-and-solarcity-agree-to-2-6-billion-merger-deal-1470050724
[23] Natural Renewable Energy Laboratory. 2016. E-Roadway Animation. Retrieved from: http://www.nrel.gov/transportation/e-roadway_animation.html
[24] National Research Council of the National Academies. 2013. *Transitions to Alternative Vehicles and Fuels.* Washington, DC: National Academies Press.
[25] Archsmith, James, Alissa Kendall, and David Rapson (2015) From Cradle to Junkyard: Assessing the Life Cycle Greenhouse Gas Benefits of Electric Vehicles. Davis Economics Energy Program. Available online at http://policyinstitute.ucdavis.edu/files/WP009.pdf
[26] Collantes, Gustavo, Jeff Kessler, and Eric Cahill (2017) Structural Determinants of Electric Vehicle Market Growth. National Center for Sustainable Transportation. Available online at https://ncst.ucdavis.edu/wp-content/uploads/2017/02/NCST-EV-TIS-U.S.DOT-Collantes-Final.pdf

Laboratory looked at the case of CNG vehicle and infrastructure growth in Argentina, to draw lessons that could be applied to FCEV markets and the supporting hydrogen infrastructure in the US.[27] The study showed the importance of a concerted long-term program to support the market development of a vehicle technology. It also showed that direct government investments on fueling infrastructure can be fairly limited if appropriate policies are in place to induce market demand for the vehicles. Once consumers see the value proposition in the vehicle technology, industry is keener to step in with investments in infrastructure (although incentives may be needed too). In general, studies show that cluster approaches to FCEV and hydrogen infrastructure deployment may be most effective and efficient. It was found for the case of the Los Angeles basin that early FCV markets (few thousand vehicles) concentrated in a few regional clusters, could be served with a sparse early network of stations (about 1% of the gasoline stations).[28]

Technology-enabled Mobility Options

Connectivity and increased access to crowd-sourced data are creating and enabling new and enhanced mobility options and new business models for providing transportation services on demand. Through shared and on-demand transportation services—such as carsharing, bikesharing, dynamic ridesharing, and ridesourcing—transportation systems could complement existing services and provide cost-effective and more efficient transportation solutions, including to areas that are not well served by fixed-route transit.

Shared Mobility Options – Ridesharing and Carsharing

Shared use mobility can be defined as the "wide variety of new technology-enabled services and tools that give instant access to new services and travel information while complementing traditional modes like fixed route transit."[29] Building upon newfound connectivity, shared use mobility has gained importance in recent years, becoming a viable mode of transportation. It should be noted that many of these concepts are not particularly new—for instance, bikesharing has been operating since the 1960s in Amsterdam. However, their significant growth can be attributed to improvements to communications technology have simplified the tasks of reserving, track vehicles, and pay for services.[30]

The "Innovative Mobility Carsharing Outlook," produced by the Transportation Sustainability Research Center at the University of California, Berkeley, reports that carshare numbers have increased from about 448,574 carshare members in the U.S. in 2010 to nearly 1.34 million members in 2014.[31] This number can be expected to increase as new services and partnerships between the public and private sector emerge.

New and existing companies are capitalizing the increased level of connectivity to connect people and services through mobile applications. For instance, the application Unmooch allows a driver giving a friend a ride to college to calculate the exact share of gasoline costs for each passenger, and sends a message

[27] Collantes, Gustavo and Marc Melaina (2011) The co-evolution of alternative fuel infrastructure and vehicles: A study of the experience of Argentina with compressed natural gas. Energy Policy 39(2): 664-675.
[28] Nicholas, Michael A. and Joan M. Ogden. 2010. An Analysis of Near-Term Hydrogen Vehicle Rollout Scenarios for Southern California. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-10-03
[29] Filler, Larry and Marc Oliphant. 2013. "Shared Use Mobility: The Next Big Thing in Transportation." Eno Transportation Center. Retrieved from https://www.enotrans.org/eno-brief/shared-use-mobility-the-next-big-thing-in-transportation.
[30] Institute of Transportation Studies Berkeley, Transportation and the Sharing Economy. *Available at:* http://its.berkeley.edu/btl/2014/winter/sharedmobility
[31] Shaheen, Susan and Adam Cohen. 2014. Transportation Sustainability Research Center – University of California, Berkeley, Innovative Mobility Carsharing Outlook, Fall 2014, *Available at:* http://tsrc.berkeley.edu/sites/default/files/Fall%202014%20Carsharing%20Outlook%20Final.pdf

through a payment app to alert the friends to their share of the bill.[32] Other companies enable people who own cars to let others rent their vehicle while not in use, such as RelayRides[33] and Turo.[34]

As the market share of transportation network companies and private transportation services increase, transportation agencies are beginning to seek partnership opportunities. The Bay Area's Metropolitan Transportation Commission, for example, is teaming with Carma,[35] Scoop,[36] and Lyft[37] to help encourage carpooling.[38]

Mobility on Demand – Linking Transit, Ridesharing, and Other Options

As shared mobility becomes increasingly popular, opportunities exist to improve mobility by linking ridesharing with transit, improving the connection among modal choices. This integration of services reduces the burden of first-mile/last-mile mobility, making travelers more likely to forgo a private vehicle in favor of a shared mode.

Different mobile applications are integrating information to provide routing and traffic guidance, information on parking and construction, real-time transit arrival times for different transit services, to mention a few. One example of this is Moovit,[39] an application that provides its 40 million users worldwide an array of transit travel options, allowing them to pick the mode most convenient for them. Other smartphone applications, such as Moovel, also serve to link mobility options by providing travel information to users. With three primary smartphone applications, MoovelTransit, RideTap, and the integrated Moovel, the company enables users to purchase tickets, discover new rides, and plan trips.[40]

A more advanced and comprehensive concept of this is known as Mobility as a Service (MaaS), a system that integrates all modes into a single and modifiable "mobility package." Helsinki is currently testing its MaaS plan, Whim,[41] which creates a centralized smartphone application ran by a public utility for booking and paying for bus, train, taxi, bicycle, and carsharing trips. Helsinki's ambitious plan seeks build an on demand system that would allow users to "purchase mobility in real time, straight from their smartphones."[42] Stateside, the integration of services is being conceptualized as mobility on demand (MOD). In May 2016, the Federal Transit Administration (FTA) announced a funding opportunity through their MOD Sandbox Program for MOD public transportation projects. FTA's MOD initiative "envisions a multimodal, integrated, automated, accessible, and connected transportation system in which personalized mobility is a key feature."[43]

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[32] Unmooch website, *Available at:* https://www.automatic.com/apps/unmooch/
[33] RelayRides website, *Available at:* https://relayrides.com/
[34] Turo website, *Available at:* https://turo.com/
[35] Carma website, *Available at:* https://www.gocarma.com/.
[36] Scoop website, *Available at:* https://www.takescoop.com/.
[37] Lyft website, *Available at:* https://www.lyft.com/.
[38] Metropolitan Transportation Commission. (2016). "There's an App for That: MTC Partners with Private Sector to Expand Carpooling." http://mtc.ca.gov/whats-happening/news/theres-app-mtc-partners-private-sector-expand-carpooling.
[39] Moovit website, *Available at:* https://www.moovitapp.com/
[40] Moovel, https://www.moovel.com/en/US.
[41] Whim website, *Available at:* https://www.moovitapp.com/
[42] Greenfield, Adam. 2014. Helsink's ambitous plan to make car ownership pointless in 10 years. The Guardian. Retrieved from http://www.theguardian.com/cities/2014/jul/10/helsinki-shared-public-transport-plan-car-ownership-pointless.
[43] Federal Transit Administration. 2016. "Mobility on Demand (MOD) Sandbox Program. https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program.html.

Technology-enabled Freight Applications and Logistics

In addition to passenger transportation, the freight industry is also undergoing significant changes, including advances in logistic practices and use of autonomous technology and new modes, such as surface and aerial drones for package deliveries. Freight-related mobile application business and service models are on the rise, ranging from apps that make freight-related processes more efficient—such as Drivewyze, a smartphone weigh station bypass app— to those that enhance e-commerce. New e-commerce services, combined with consumers' increased expectation of faster deliveries, are pushing freight towards individual deliveries mechanism, such as mini-distribution centers and increased fleet of smaller trucks, cars, bike deliveries. This is opening up a market for companies to provide on-demand movement of goods, such as UBERCargo, EasyVan and GoGoVan that have had significant success in Hong Kong and are currently expanding to other countries.[44]

Within the US, Uber began to use their already existing network to experiment with local/ individual delivery services, with the aim of becoming as disruptive in logistics and urban deliveries as it has been in the taxi business. Uber is already running a lunch delivery service, UberEATS, in Atlanta, Washington, DC, Chicago, Los Angeles, New York, Barcelona, and Toronto—a service that is rapidly expanding—and UberRUSH in New York to provide on demand bike courier service. Furthermore, in Washington, DC, Uber can provide rapid delivery of household supplies, and the company is reported to be in talks to set up same-day delivery for various retailers.[45] In the urban realm, some speculate that Uber could dominate freight services in large part because it has limited costs compared to UPS or FedEx, which have to maintain vehicle fleets.[46] Applications such as Convoy and Transfix aim to streamline the process of pairing shippers with suppliers, thus optimizing the freight shipment matching process and reducing the share of empty "deadhead" miles in the freight system, which are currently around 20%.[47]

Although not a new concept (especially internationally), urban distribution centers are being considered as a viable alternative within the US as convenience stores and other locations are seizing their already strategic (and accessible) location for consumers to pick up their orders at their convenience within a given timeframe. With e-commerce on the rise, creating mechanisms to ensure customers receive their packages is imperative, especially in urban areas, where it would be easy for a package to be stolen from a doorstep. These lockers also make delivery more efficient, as it is much easier to drop several packages off at one location as opposed to dropping individual packages off at several locations.[48] They also may enable a person to pick up goods on their way to/from work using transit, thereby supporting car-free living.

Changes to urban goods movement are also in progress as cities define and implement new mandates on retailers, such as off-hour delivery (as Barcelona has done since 1998 and New York City has piloted) and requirements for storage space. This, combined with the prevalence of online commerce and the emergence of on-demand delivery, is pushing the freight industry to improve their efficiency. As such, a new vision of the freight service operation is being implemented in many cities, which are developing

[44] John Russel. 2015. Uber's Latest Experiment Is Uber Cargo, a Logistics Service in Hong Kong. Retrieved from https://techcrunch.com/2015/01/08/uber-cargo/

[45] The Economist. 2015. Uber – Driving hard. June 13 edition. http://www.economist.com/news/business/21654068-taxi-hailing-company-likely-disrupt-delivery-business-driving-hard

[46] The Economist, "Uber - Driving Hard."

[47] California DOT. Trucking Industry Overview. http://www.dot.ca.gov/hq/tpp/offices/ogm/key_reports_files/National,%20Technical%20studies/Trucking_industry_overview.pdf

[48] Greg Bensinger. 2012. "Amazon's New Secret Weapon: Delivery Lockers." The Wall Street Journal. Retrieved from http://www.wsj.com/articles/SB10000872396390443545504577567763829784538.

systems to integrate the efforts of the different entities in the supply chain, allowing for a better and more efficient movement of goods from end-to-end.[49]

Drones are also likely to have important impacts on package delivery in urban areas. For example, the Swiss company Swiss Post Ltd and German automaker Mercedes-Benz have both started coordinating (independently) with California aerial drone manufacturer Matternet to test the feasibility of using aerial drones for package delivery through an integrated delivery service.[50] Delivery by drones has many applications, including "delivery to peripheral areas" to "transporting emergency supplies."[51] Additionally, major retailers like Amazon are preparing to begin using drones for delivery purposes. Alternate forms of drones are also being developed for delivery purposes. For instance, companies such as Starship Technologies are seeking to deploy ground package delivery drones in U.S. cities. [52,53]

Advances in System Management and Infrastructure

New and enhanced technologies are influencing how systems and services are being managed. Enhanced communications systems enable the flow of increasingly larger volumes of data. This abundance of data in conjunction with advanced algorithms (e.g. algorithms of the Kalman Filter family) and processing speed enables agencies to track all of its assets in (near) real time, for example for accurate vehicle tracking and scheduling and assessing transit vehicle ridership and crowding. In addition, agencies and customers can directly gather relevant information through crowdsourced data (e.g., Twitter, Facebook, Instagram and other social media platforms). Agencies that implement the infrastructure to collect, process, and store these vast amounts of data, are well positioned to efficiently allocate their resources based on reliable forecasts and can better control their operation as well. Very important to fully exploit this potential is the standardization of data and integration of data flows across agencies (sometimes referred to as interconnection).

Electronic Payment Methods

Recent advances in smartphone technology have enabled the use of mobile payments (i.e., the use of a mobile device that is connected to a credit card or bank account to pay for goods rather than cash, check, or credit card swipe, both online and in person. Companies such as PayPal and Apple sit at the forefront of these technologies. Mobile payment have enabled travelers to easily and efficiently pay for transportation services and more easily travel in a multimodal system. Transit agencies are using advances in payment and enhanced ITS technology to streamline and improve fare collection, scheduling and routing of transit services.

TNCs like Uber and Lyft have benefitted significantly from mobile payment methods. Braintree, which is owned by PayPal, provides a payment platform for these on-demand travel applications and allows users to seamlessly pay for their travel. In addition, some transit agencies are experimenting with smartphone applications that allow users to purchase and store tickets on their mobile device. Portland's TriMet app for example allows users to purchase tickets. This eliminates the need for a paper ticket and enables

[49] Texas Transportation Researcher Technology. 2015. New Concepts Drive Future Freight Movement Investments. Volume 51, Number 4. https://tti.tamu.edu/2015/12/01/technology-new-concepts-drive-future-freight-movement-investments/

[50] Matternet website, *Available at:* https://mttr.net/

[51] Whelan, Robbie. 2014. Are Drones the Future of Air Freight? Retrieved from http://www.wsj.com/articles/are-drones-the-future-of-air-freight-1436468089.

[52] O'Kane, Sean. 2017. These six-wheeled robots are about to start delivering food in the US. The Verge. *Available at*: http://www.theverge.com/2017/1/18/14300054/food-delivery-robots-postmates-doordash-us-launch

[53] Starship website, *Available at:* https://www.starship.xyz/

users to avoid the inconvenience and frustration of purchasing tickets at a kiosk or carrying exact change for bus fare.[54]

Real-time Traveler Information

Many state and local transportation departments transmit information through 511 mobile applications, transit agencies publish real time information through their own applications, and private application companies, like Waze/Google, serve as an additional resource for travelers. State DOTs and local governments are increasingly turning to the private sector to acquire, process, and share data. Most notably, cities and states across the country are entering into data sharing partnerships with Waze, as well as other companies, such as INRIX and HERE. Missouri DOT for instance had a partnership with the latter. Early adopters to this were Boston, MA; Los Angeles County, CA; Utah, Florida, and the New York Police Department. Transit agencies are also adopting social media to achieve a two-way interaction between agency and users, increasing transparency and accountability, while improving how they monitor and provide information about their services.[55]

Integrated Corridor Management

Transportation agencies also are using technology to better manage and operate transportation systems as coordinated networks. The concept of Integrated Corridor Management (ICM), developed by the US DOT, is that transportation networks will realize significant improvements in the efficient movement of people and goods through institutional collaboration and proactive communication and integration of operations along major corridors, which may include interstates, arterials, and transit services. Through an ICM approach, transportation agencies manage the corridor as a multimodal system and make operational decisions using real-time data to optimize performance across the corridor as a whole.[56] ICM is the center of "Tier 2" ITS initiatives.[57] Examples of ITS service packages that could be deployed in ICM strategies could include network surveillance, traffic signal control, interactive traveler information, and others. These would all benefit from advances in data collection, data transmission (volume and speed), analysis (e.g. image processing), and algorithms for the rapid allocation of resources (e.g. emergency response).

Active Transportation and Demand Management

A related concept being advanced at the Federal, state, and regional levels is called Active Transportation and Demand Management (ATDM), which focuses on the active management, control, and influence of travel demand, traffic demand, and travel flow of transportation facilities. ATDM can include multiple approaches spanning active demand management (e.g., dynamic pricing, on-demand transit, predictive traveler information), traffic management (e.g., adaptive traffic signal control, dynamic lane reversal, dynamic shoulder use, adaptive ramp metering), and parking management (variably priced parking, dynamic parking reservation systems).[58] In New York City, for example, the city is piloting the PARK Smart program, which is intended to increase the availability of parking, increase safety, reduce double-parking, reduce pollution, and reduce congestion from circling vehicles. The program uses dynamically priced parking to reduce demand and discourage drivers from staying in a metered space

[54] TriMet website. Available at: http://trimet.org/app/index.htm
[55] Newcombe. 2015. "3 Advances in Transit Technology." http://www.govtech.com/dc/articles/3-Advances-in-Transit-Technology.html
[56] ITS Joint Program Office, Integrated Corridor Management, *Available at:* http://www.its.dot.gov/icms/index.htm
[57] Tier 1 is centered on regional integration and Tier 3 is centered on basic system operations and infrastructure.
[58] FHWA, ATDM Program, *Available at:* http://www.ops.fhwa.dot.gov/atdm/about/overview.htm

longer than necessary.[59] Similar programs have been implemented or piloted in San Francisco and Washington, DC.

Social Media/Gamification

In "Urban Mobility at a Tipping Point", Bouton, Knupfer, Mihov, and Swartz note that software companies are playing a role in influencing the mode that travelers use. A similar conclusion is provided in Eno Center for Transportation's 2016 report "Emerging Technology Trends in Transportation," indicating that if designed well, a smartphone application can have a profound impact on how travelers choose to transport themselves.[60]

In addition, there are opportunities for the public sector to provide incentives for behavior changes that support environmental or other outcomes through incentives. A start-up company called Urban Engines aims to provide analytics, individualized trip plans and micro-incentives to its users.[61] Another start-up in this field is Metropia, which aims to link incentives with local businesses for time and route shifts.[62] The goal of the app is to provide rewards for off-peak driving including the ability to obtain rewards by "reserving" trips on the app. The mobile app predicts future travel times and assigns reward points to the departure times and routes that cause less impact to the roadway system. Another similar project in Europe is Mobidot, which uses a smartphone-based system to influence travel behavior.[63] These apps sometimes use the concept of "gamification", in which social competition is used to reward users of apps through "virtual prizes" and positive reinforcement, rather than financial incentives.[64]

Advanced Infrastructure

Technology can also be used within transportation infrastructure to support asset management, including monitoring the condition of bridges and pavements (along with use of mobile technologies, such as drones, to reduce the cost of bridge inspections). Moreover, the emergence of vehicle electrification as a key trend in the automotive industry has led to an interest in the deployment of charging infrastructure, commonly known as electric vehicle supply equipment (EVSE). While the 1990s saw some competition between the two main charging technology paradigms—inductive and conductive—currently the dominant technology is conductive charging. The charging technology itself is by no means an emerging technology, but the communications and software around it have seen recent developments and are important for the integration of this infrastructure into regional systems. Of particular interest is investments in higher-power charging infrastructure. The equipment in the category known as direct current fast charge (DCFC) is rated at 50-60kW and typically used to support electric vehicle mobility at the regional/corridor level. DCFC networks require special planning, to account for a variety of factors, including vehicle energy use over a given corridor, access to three-phase power, opportunities for collocation of storage and solar systems, etc. Connectivity of charging infrastructure, although adding a cost premium to installations, enable a series of services of benefit to users (e.g. mobile interfaces that provide information on availability of charging equipment at a site) and utilities (e.g. smart charging) in particular. Even higher power equipment is used for the charging of electric buses on route. Such

[59] New York City Department of Transportation. PARK Smart. Available at http://www.nyc.gov/html/dot/html/motorist/parksmart.shtml.
[60] Shaheen, Cohen, Zohdy, Ismail, and Kock. 2016. "Smartphone Applications to Influence Travel Choices: Practices and Policies." U.S. Department of Transportation. Retrieved from http://www.ops.fhwa.dot.gov/publications/fhwahop16023/fhwahop16023.pdf.
[61] Urban Engines. *Available at:* https://www.urbanengines.com/about/.
[62] Metropia. *Available at:* http://www.metropia.com/solutions.
[63] Mobidot website. *Available at:* http://www.mobidot.nl/en/index.php.
[64] McNulty, Mary Ann. 2011. Gamification In Travel Management: Is This The Next New Thing To Drive Compliance? Business Travel News. *Available at:* http://www.businesstravelnews.com/Travel-Management/Gamification-In-Travel-Management--Is-This-The-Next-New-Thing-To-Drive-Compliance-/?a=proc

equipment, known as overhead chargers, operates a power levels typically in excess of 300kW. New electric buses using overhead chargers showcased early applications of vehicle automation, as the vehicle pulls into the charging deck by itself.

While investments are currently directed to conductive infrastructure, there has been much development on inductive wireless charging—a technology known as Shaped Magnetic Field in Resonance, or SMFIR. One disadvantage of inductive charging has been its lower efficiency. However, leading companies in this space, like WiTriCity, are achieving high charging efficiencies in excess of 90%. This progress is very relevant to emerging transportation technologies: automated vehicles will tend to use electric drive platforms, and wireless charging is much more suitable to their operations than connector charging. Inductive wireless charging can be implemented using on-ground charging pads (requiring minimal site upgrades, for example in residential garages), or using pavement-embedded infrastructure, typically on parking areas.

In more advanced applications, inductive charging technology can also be done while vehicles are moving, in which case cables are embedded in the pavement along (parts of) a given route. This technology is particularly suitable for transit, as vehicle operates over fixed routes, and can charge bus over strategic segments of the route using power typically in the order of 100kW. One example of an application of this technology is taking place in South Korea.[65] Similar technology is being tested in the US and other countries. New technology for Smarter Highways development in the Netherlands includes dynamic paints and glowing lines that charge at daytime, and glow at night for eight hours[66].

Closer to home, Missouri DOT is looking at a concept for Solar Roadways as part of their Road to Tomorrow initiative. The Road to Tomorrow effort is exploring a range of technologies, including smart pavements, which provide digital, communication, and information services to the Missouri DOT, motor carriers, and other commercial fleet operators and private drivers on a subscription basis.[67] The Ray Foundation is also testing new technologies to create a "regenerative highway ecosystem" on their 18-mile stretch of I-85 in Georgia. The Ray have already implemented several pilot projects, including solar-powered vehicle charging, tire safety check station, and solar-paved highways.[68] Solar roadways are under various stages of development by companies such as Wattway, and could power homes or clear snow off road via heat release.[69]

New Forms of Transportation

New types of vehicles and modes of transportation also have been proposed or are being developed as prototypes. One of the most notable is the Hyperloop, a conceptual high-speed transportation system initially championed by Elon Musk. The Hyperloop uses electric propulsion to move passenger or cargo pods through a tube in a low-pressure environment at very fast speeds. These autonomous pods are touted as being environmentally friendly, quiet, and free of delay, weather concerns, and pilot error. The Hyperloop is in testing with a goal to move cargo by 2020 and passengers by 2021.[70]

[65] Barry, Keith. 2015. "In South Korea, Wireless Charging Powers Electric Buses." Retrieved from: http://www.wired.com/2013/08/induction-charged-buses/.
[66] Smarter Highways website. *Available at:* https://www.studioroosegaarde.net/project/smart-highway/info/
[67] Missouri DOT, Road to Tomorrow, http://www.modot.org/road2tomorrow/
[68] The Ray Foundation, website *Available at:* http://theray.org/
[69] See, for example, the Wattway website. *Available at*: http://www.wattwaybycolas.com/en/
[70] Hyperloop One, https://hyperloop-one.com/.

Another next generation technology concept is the Freight Shuttle, initially developed by the Texas A&M Transportation Institute. The concept of the Freight Shuttle is to move intermodal containers on "emissions-free, electric-powered transporters on elevated guideways in the medians of highways or other rights-of-way over distances of up to 500 miles."[71] Passenger drones also have been developed by firms like e-volo, based in Germany, and Ehang, based in China. These small aircraft are envisioned by some as going beyond the recreational and sport aviation market to provide autonomous air-taxi services, although there are many regulatory, liability, and infrastructure issues surrounding the technology.[72]

It is unclear, however, whether these proposed advanced technology modes will achieve significant levels of adoption. For instance, when the Segway electric scooter was initially unveiled, it was heralded by its developers as a new form of transportation that would revolutionize mobility. However, today Segways generally serve a limited set of applications.

Synergies Across Technology Trends

Collectively, the technologies trends described above are advancing and have the potential to come together in ways that could yield dramatic changes in the movement of people and goods within metropolitan areas, including the Greater St. Louis region, through "smart" transportation (see Figure 3). As highlighted in a recent white paper by McKinsey and Company, the interconnected nature of these technological trends underscores the importance of considering them together.[73]

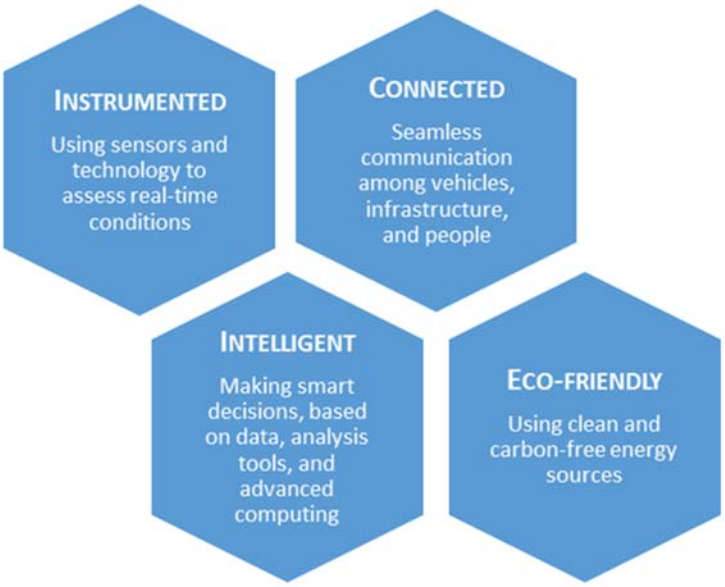


Figure 3. Characteristics of a Future "Smart" Transportation System (Source: ICF)

Improved Multi-modal Integration and Mobility as a Service

Several technologies have the potential to work harmoniously towards facilitating multi-modal transportation, such as improved data analytics, real-time travel and transit information, diverse mobility business models, connectivity, and big data. Several of these technologies have already begun to coalesce and facilitate entirely new travel experiences. For example, trip aggregator applications that leverage smartphone technology, real-time transit information, and traffic data allow for trip-by-trip route recommendations that offer travel choices across several modes. Several private companies currently offer these services, such as Ridescout and Google Now, and some public transit agencies are planning on pursuing their own applications. [74] These services reduce the burden of combining multiple modes into a single trip. Multi-modal travel can be further

[71] Freight Shuttle International, https://www.freightshuttle.com/.
[72] "Passenger drones: Those incredible flying machines." (June 25, 2016) *The Economist.* Science and Technology.
[73] See: https://about.bnef.com/white-papers/integrated-perspective-future-mobility/
[74] Transportation and Sustainability Research Center. October 2016. Mobile Apps and Transportation: A Review of Smartphone Apps and a Study of User Response to Multimodal Traveler Information. http://innovativemobility.org/wp-content/uploads/MobileApps_UCCONNECT.pdf

incentivized by allowing an integrated fare payment, and coordination between different modes, such as light rail and ridesourcing services.

The advent of these individual technologies has also spurred discussion over whether personal mobility could transition to a mobility as a service (MaaS) system. In MaaS, users pay flat monthly fees in exchange for access to many transportation modes, and essentially purchase transportation packages.[75] This first MaaS provider, Whim, is currently undergoing testing in Europe with goals of expanding globally.[76] Like trip aggregating applications, Whim allows users to chart a course in an app, and informs users of the optimal means of making the trip, including options from several public and private services. Whim then goes an important step further than standard trip aggregating applications and will make any necessary bookings and payments to those services in the charted trip.[77] In a MaaS system, public agencies and private companies alike negotiate the terms of including their transportation services. It is likely that the emerging of MaaS systems will change the mobility market and service landscape in profound ways, one of which could be a restriction in the demand for traditional bus services in place for more point-to-point modes.[78]

Electrification, Autonomy, and Shared Mobility

There is a strong and often touted argument for considering trends in AV, shared mobility, and electric vehicles together, rather than as distinct trends. Automation and shared mobility service models have the potential to radically grow the electric vehicle market due to several important synergies between the three technologies. The logic of these synergies is as follows: First, shared mobility assists EV technology by alleviating two common barriers to EV deployment: range anxiety and inadequate consumer knowledge. If vehicles are operated by private fleets, individual consumers need not worry about where and how to recharge or repair EVs. Further, the vast majority of trips are below the range restrictions of today's electric vehicles, so travel selected on a trip-by-trip basis is subject to less range concern.

Second, electrification assists shared mobility applications by providing a cheaper fuel for high-mileage vehicles. Fueling an EV is often 50% cheaper than its gasoline equivalent,[79] and since shared-automated vehicles are likely to generate a lot of total mileage (A typical NYC taxi, for example, can travel 70,000 miles per year)[80], these per-mile costs are likely to be an especially important consideration, giving EVs an advantage in shared-use applications as compared to personal use.

Third, automation assists shared-use applications by reducing driver costs, prompting major TNCs like Uber and Lyft to invest heavily in automated driving capability. It also allows EVs to be used in shared-use applications more easily since full-time drivers will not need to put their work day on pause while their car refuels. Finally, automation supports electrification since EVs can be recharged more easily than fossil fuel-based systems.

Collectively, these synergies (and others) make these three seemingly distinct technologies likely to be interrelated, and current industry actions suggest that this hypothetical convergence is on track to become

[75] ITS Finland. 2014. 'Mobility as a Service' – the new transport model? http://www.fiaregion1.com/download/events/its_supp_et214.pdf
[76] MAAS Global. http://maas.global/whim-the-worlds-first-all-inclusive-mobility-service-promises-to-change-urban-travel-forever/
[77] The Economist. 2016. It starts with a single app. Sept 29, 2016. *Available at:* https://goo.gl/AqFkh8
[78] Hensher, D.A. 2017. Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: Are they likely to change? *Transportation Research Part A: Policy and Practice* 98(1):86-96. http://dx.doi.org/10.1016/j.tra.2017.02.006
[79] U.S. DOE eGallon. *Available at:* https://energy.gov/maps/egallon
[80] NYC Taxi and Limousine Commission. 2014. Taxicab Fact Book. http://www.nyc.gov/html/tlc/downloads/pdf/2014_taxicab_fact_book.pdf

a reality. There are several industry pilot efforts to make shared autonomous vehicles, and each of them uses some degree of electrification (either plug-in hybrids or electric vehicles). For examples, Local Motors is testing Olli,[81] an autonomous and all-electric shuttle for first/last mile transportation; nuTonomy is using EVs in its autonomous vehicle ride service in Singapore and Boston,[82] and Lyft and GM have stated plans to introduce the EV Bolt into ridesharing applications.[83]

Smart Cities

While the definition of a "Smart City" varies across sources, the concept can be defined it as a city that "has digital technology embedded across all city functions." The concept of Smart City has the capability to combine most (or all) of the technologies identified in this document, and to include advances in non-transportation fields as well. As such, a Smart City can be better defined in more detail as "a system of interconnected systems, including employment, health care, retail/entertainment, public services, residences, energy distribution, and transportation (of both passengers and freight)…tied together by information and communication technologies (ICT) that transmit and process data about all sorts of activities within the city."

McKinsey & Company's *The Internet of Things*[84] states that cities are already becoming smarter by utilizing and combining technology capabilities to run smarter activities. The report identifies six capabilities that a Smart City should have, which fall under two broad categories: Information and Analysis (1-3) and Automation and Control (4-6):

1. **Tracking behavior.** Monitoring the behavior of persons, things, or data through space and time.
2. **Enhanced situational awareness.** Achieving real-time awareness of the physical environment.
3. **Sensor-driven decision analytics.** Assisting human decision making through deep analysis and data visualization.
4. **Process optimization.** Automated control of closed (self-contained) systems.
5. **Optimized resource consumption.** Control of consumption to optimize resource use and access network.
6. **Complex autonomous systems.** Automated control in open environments with great uncertainty.

While these visions of the future may suggest a somewhat "utopian" view, it is important to recognize that the future may play out in unexpected ways, and several authors have suggested different potential future technology directions or trajectories, such as[85]:

- Private Autonomy, in which autonomous vehicles are widespread but largely operated in private vehicles. In this scenario, suburban sprawl and vehicle travel demand could increase significantly, or new strategies such as demand-driven congestion charges and incentives for electric vehicles may be instituted.

[81] CNN. 2016. This talking, electric, self-driving bus is coming to a city near you. http://www.cnn.com/2016/10/20/world/ollis-electric-bus/. For more information, see the Local Motors website at: https://localmotors.com/olli/
[82] Green Car Reports. 2016. Autonomous Renault Zoe electric car to be tested in Boston by nuTonomy. *Available at:* http://www.greencarreports.com/news/1107434_autonomous-renault-zoe-electric-car-to-be-tested-in-boston-by-nutonomy
[83] Reuters. 2017. Exclusive: GM plans to build, test thousands of self-driving Bolts in 2018 – sources. http://www.reuters.com/article/us-gm-autonomous-exclusive-idUSKBN15W283
[84] Chui, Michael, Loffler, Markus, and Roberts, Roger. 2010. *The Internet of Things*. McKinsey Quarterly. Retrieved from http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things.
[85] Organizations such as Deloitte University Press, McKinsey & Company and Bloomberg, and the U.S. Department of Energy have highlighted multiple scenarios for the future, which these examples are based upon.

- Seamless Mobility, in which autonomous vehicles are pervasive as shared on-demand vehicles, potentially linking to fixed-route transit services and connected with other options, such as bike-sharing. In this scenario, individual vehicle ownership essentially disappears, and people utilize all forms of transportation as an on-demand service, potentially significantly reducing parking needs in urban areas.

In addition, there may be a range of other options, such as more limited application of autonomous vehicles (e.g., initially primarily to support freight delivery and specialized applications, such as certain types of transit services) and different levels of adoption of clean vehicle technologies. In addition, it is important to recognize that the needs and issues in regard to technology adoption over the next 5-10 years will be considerably different than those of 2050.

3. STRATEGIC GOALS

The EWG has identified ten *Guiding Principles* to guide the region's transportation planning and policy (Figure 4). The Principles challenge the region to make the connection between transportation and the broader society. Many of these areas also have a high potential to be affected by technology.

What does the St. Louis Region want to achieve in relation to emerging technologies?

These principles relate closely to national transportation performance measures that states and metropolitan planning organizations will be required to report on, which include:[86]

- Pavement condition on the Interstate System and on remainder of the National Highway System (NHS);
- Bridge condition on the NHS;
- Fatalities and serious injuries—both number and rate per vehicle mile traveled--on all public roads;
- Number of non-motorized fatalities and non-motorized serious injuries;
- Performance of the Interstate System and the remainder of the NHS, measured in regard to the percent of reliable person-miles traveled;
- Freight movement on the Interstate System, measured in regard to reliable truck travel time;
- Traffic congestion – measured in relation to both annual hours of peak hour excessive delay per capita and modal share (percent of non-single occupancy vehicle travel); and
- On-road mobile source emissions.

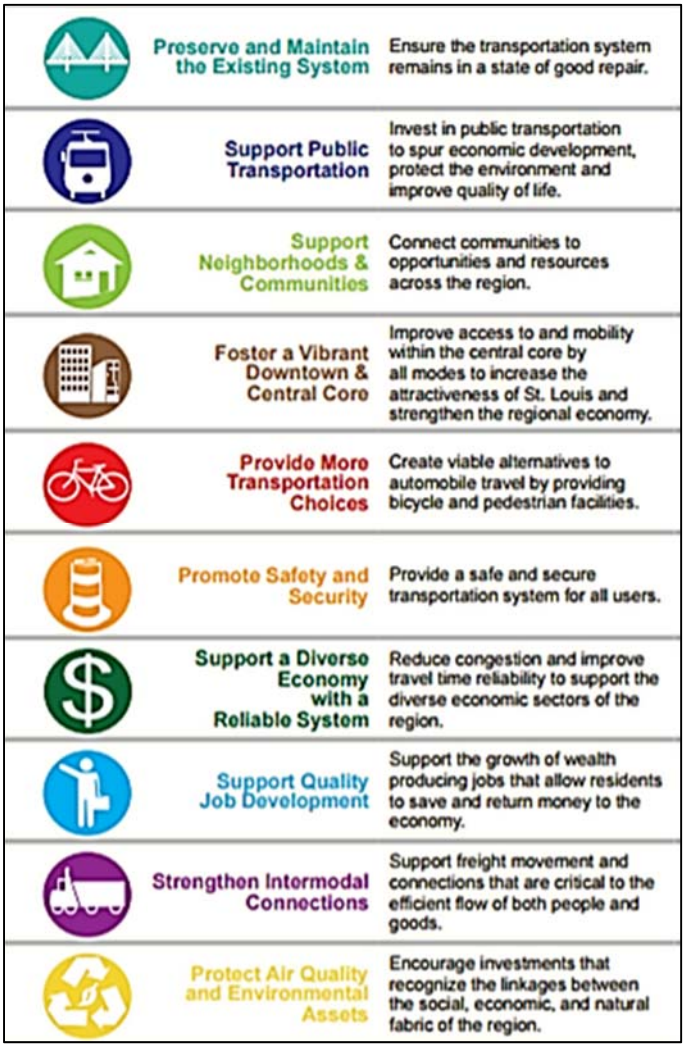


Figure 4: EWGCOG's Ten Guiding Principles (Source: EWG)

The ten *Guiding Principles* form the basis of the goals of the Strategic Plan; the Plan defines impacts as positive or negative to the extent that they support or challenge the *Guiding Principles*. In some cases new technologies, such as automation and infrastructure connectivity, may bring a windfall of positive impacts, but there are other instances where technological change may yield adverse consequences. Even in cases where technological change is likely to be positive, there is uncertainty in the extent of that impact, and the St. Louis region would do best to

[86] For more information on the final performance measure rules, see FHWA's Transportation Performance Management website, available at: https://www.fhwa.dot.gov/tpm/rule.cfm.

prepare for, and shape, these impacts in its regional transportation planning, policy, and investment decision making.

Emerging Transportation Technology Strategic Goals

In regard to the ongoing rapid technological changes in the transportation sector, this Strategic Plan identifies three goals associated with emerging transportation technology and its integration in regional planning:

1. **Harness positive impacts from technology**

   Foster emerging transportation technologies that help advance the region's vision and Guiding Principles through policies, plans, and strategic investments.

2. **Address potential negative impacts from technology**

   Consider the risks of emerging transportation technologies in the region's planning and investment decision making to help mitigate potential adverse consequences on the region and its residents.

3. **Support the region to be a laboratory for innovation**

   Bring innovation to the region through application of emerging transportation technologies that support economic growth and quality jobs.

The purpose of the Strategic Plan is to delineate a path of action whereby these technology-associated goals lead to policies and actions the EWG can integrate into its transportation planning process and regional collaborative activities. The plan does so by addressing the following key questions:

- What are the unique strengths and weaknesses of the region in relation to technology adoption?
- What are the potential opportunities and treats of technologies?
- What implications will emerging transportation technologies have on transportation investments and needs?
- What policies areas should the St. Louis region focus on? and
- What can the St. Louis region do to better prepare for these emerging technologies?

4. DEVELOPMENT OF THE STRATEGY

Throughout the process of developing a strategy to achieve these goals, EWG sought to integrate: i) the vision of the St. Louis Region, laid out through the *Guiding Principles*, ii) the priorities for the St. Louis regional transportation system, as portrayed in the Long-Range Transportation Plan *Connected 2045*, and iii) the foundation of priorities and plans in the region including the region's *Intelligent Transportation Systems (ITS) Architecture and Deployment Plan*. The development of this strategy involved both national-level and regional-level input, including:

A robust literature review. Literature and other information pertaining to current technological trends was investigated. Sources included reports from government institutions, think tanks, and consulting firms, as well as academic peer-reviewed research, industry press releases, and other reporting on industry developments. This action also entailed an analysis of documentation that relates specifically to the St. Louis region, such as the regional ITS Architecture and the Long Range Transportation Plan.

A regional stakeholder survey. A transportation technology survey was developed and conducted for stakeholders in the St. Louis region, including members of the many state, local, and municipal government agencies, employers, educational institutions, and non-profit organizations in the region.[87] Recipients were asked a series of questions regarding their state of knowledge, planning and opinions around emerging technologies. The survey also asked respondents to list any particular regional advantages or disadvantages in regards to how easy or difficult it might be to maximize the positive impact of new transportation technologies. Lastly, the survey inquired about how respondents would view efforts by the St. Louis regional government to pursue technology adoption as a means to improve transportation and general quality of life in the region, and if they had any particular recommendations.

A series of expert interviews. Interviews were conducted with thought leaders on the topic of advanced technology and transportation, which included academics, industry leaders, consultants, and staff from public agencies with experience integrating technology into transportation programs (see Appendix A for a list). Fifteen (15) interviews were conducted between December 2016 and February 2017. Interview subject matter varied according to the area of expertise of the interviewee, but topics covered over the course of all interviews included the state of technological advancement, best practices for responding to technology change, and impacts of technology. Additionally, interviewees were asked to tailor this information to the St. Louis region to the extent possible.

Building on this information, and in light of the goals of this plan, a **Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis** for the region was conducted to determine the key areas of focus for the region. The SWOT analysis included an assessment of conditions in the St. Louis region in relation to technology deployment—strengths and weaknesses—and an assessment of the potential implications of technology, both positive and negative—as opportunities and threats. The SWOT analysis includes the broad opportunities and threats that might arise from new technologies generally and within the region ("external" factors), as well as regional strengths and weaknesses associated with the adoption of emerging

[87] The survey was open online from January 27, 2017 to February 21, 2017 and received 158 total responses.

transportation technologies and the application of these technologies ("internal" factors). These internal strengths and weakness were determined largely based on the results of the stakeholder survey.

As shown in Table 1, the SWOT analysis revealed many positive attributes of the region, as well as several weaknesses or challenges. It also revealed a wide array of opportunities for transportation technologies to contribute positively to regional goals, as well as some potential threats or adverse impacts that should be considered in future plans, policies, and programs.

Table 1: SWOT Analysis for Transportation Technologies in the St. Louis Region

	To Leverage	To Overcome
Internal	**S**trengths • Multi-modal transportation system • Major freight hub • Mid-size region, potentially well geared toward pilot testing • Intelligent transportation systems (ITS) infrastructure • Interest from stakeholders	**W**eaknesses • Fragmented and complex government structure, across two states and multiple local governments • Population decline in urban core • Social barriers, including perceptions of inner-city crime • Sprawling region with low density and heavily car-centric travel patterns • Funding constraints
External	**O**pportunities • Potential positive technology impacts: - Significant safety improvements - Reduced travel costs - Increased travel choices - Improved access, particularly for those currently with limited mobility and those without access to private vehicles - Improved system reliability - Possible transit service improvements and reduction in cost - Optimized supply chain, yielding economic benefits - Quality job development in emerging technology fields - Air pollutant and greenhouse gas reductions - Potential for clean energy generation • Federal grant programs • Private sector funding	**T**hreats • Potential adverse technology impacts: - Reduced funds from traditional transportation funding sources - Increases in vehicle travel and congestion - Increases in sprawl / decentralized development patterns - New options draw people off of public transit - Gaps in access by those who cannot afford - Cyber-security threats associated with new technology - Reduction in employment, as jobs related to driving could be displaced

The SWOT analysis assists in development of a strategy for the region to capitalize on regional strengths and take advantage of the benefits of emerging transportation technologies, while mitigating potential risks or threats from technology.

The following two sections of the plan provide more detail on these attributes.

5. ASSESSING THE ST. LOUIS REGION'S READINESS TO DEPLOY EMERGING TECHNOLOGIES

What are the region's strengths and weaknesses in relation to technology deployment?

While technology is evolving largely driven by the private sector, the public sector and agencies play an important role in policy and investments that can advance or shape the role of transportation technology adoption. The section discusses specific conditions in the St. Louis region that could make the region especially effective at integrating new technology, or face challenges. In essence, it explores the readiness of the region to adopt new technology and harness its most positive effects. The section heavily relies on the results of a survey to stakeholders in the St. Louis region. Overall, survey respondents indicated that there were both positive and negative aspects of the region in regards to technology deployment, with overall impressions being slightly more negative; 74.2% of respondents said there are unique conditions in St. Louis that create challenges, as opposed to 64.9% saying there were unique strengths.

Regional Strengths

Diversity of Transportation Modes

When prompted to elaborate on specific regional advantages, multiple survey respondents noted the diversity of current transportation options in the St. Louis area. In particular, respondents noted the presence of the regional light rail system, MetroLink, as well as the presence of major ports and airports. As the landscape of transportation technology shifts, having different modes to augment and work from will likely serve as an advantage. In particular, a central rail system is important, and analysts have speculated that while it may be more difficult to invest and build new rail systems now, it is beneficial to invest in existing ones, as they may serve as essential complements to future shared ride services.[88]

Geography

The St. Louis region has several geographical advantages at both a large and small scale. At the larger scale, survey respondents noted the region's central location within the United States and its status as a "freight hub" as one of the leading metro areas in the U.S. in terms of freight movement. St. Louis is home to six Class I Railroads, four Interstate highways, two major commercial/cargo airports, and a large inland port.[89] At the local level, respondents noted that the region has moderate size and proper density to allow for testing new modes without disturbing the system or clogging up key routes. One respondent pointed to "amazingly low" instances of congestion, allowing more agency resources to be focused on innovating new ideas rather than increasing capacity. Also, the diversity of land use in the St. Louis region—with a mixture of rural, suburban, and urban spaces—provides a test-bed for different technology applications. The diversity in urban form will likely translate to instances where current transportation systems are ripe for augmentation with new solutions.

[88] Morgan Stanley. 2016. Insight North America. Cities & Shared Mobility – A Policymaker and Investor Guide.
[89] East West Gateway Council of Governments. 2017. Our Region. *Available at:* http://www.ewgateway.org/OurRegion/ourregion.htm

Enthusiasm from Stakeholders

Overall, survey respondents indicated high levels of understanding and enthusiasm for new technologies. Over 85% of survey respondents indicated at least some understanding of all technologies except technology-enabled freight applications (e.g. platooning). Respondents were also enthusiastic about the prospect of further research, as 74.2% indicated that it would be "valuable for the region to undertake efforts to improve information/understanding of emerging technologies" (only 2.3% said no, the rest said "possibly"). Since any efforts to pilot or investigate new technologies will likely require financial and political support, as well as inter-agency collaboration, this level of enthusiasm is positive. In addition, the region is home to a number of innovative institutions including: four research universities, Danforth Plant Science Center, CORTEX, T-REX, Monsanto, and Boeing.

Institutional Precedents and Early Actions

Several survey respondents pointed to past successes in other areas of local government as evidence for regional strengths. Some of the programs/initiatives mentioned include the MoDOT Gateway Guide, the integration of real-time arrival info for MetroLink, and the Gateway Green Light program in St. Charles County,[90] which helps synchronize traffic lights across the county. In particular, the Gateway Green Light program represents an example of inter-agency collaboration as well as success in winning a federal grant program—both of which could be valuable tools for integrating emerging technology. To help facilitate growth in freight, the EWG and the Leadership Council of Southern Illinois helped establish the St. Louis Regional Freightway, an all-purpose authority for freight operations and opportunities within region.[91]

ITS Infrastructure

The St. Louis region benefits from having already deployed a significant amount of ITS infrastructure. Within the region, nearly a thousand traffic signals are already fiber-optically linked together, and this fiber-optic network could be a foundation for further connectivity to vehicles and other devices. The regional also has developed a robust ITS Architecture and Deployment Plan, which provides a framework for further connectivity among systems and deployment of associated infrastructure, including an effort to establish a communications platform for sharing traffic, signal, and incident data from a mixture of regional networks in a standardized manner. Other deployed technologies include automatic smartcards for transit payment, central computerized traffic signal control systems, and automatic vehicle location systems for Metro. These technologies may serve as a building block on which to deploy new technology; centralized and robust data will be essential for deploying, testing, and refining new transportation modes or service adjustments.

As noted in the St. Louis Regional ITS Architecture and Deployment Plan, Missouri and Illinois each have extensive fiber optics and road instrumentation on their Interstate systems in the St. Louis Region, with spacing and locations of devices that are conducive to connected vehicle communications. Likewise, major arterials and highways maintained by MoDOT and IDOT along with City of St Louis, St Louis County and St Charles County, and smaller cities throughout the region, boast ITS/traffic infrastructure. The expansion of this infrastructure, along with the completion of fiber optic communications links, will facilitate the integration of vehicle-based data in the future for functions such as traffic signal operations, collection of

[90] Green Light website available at: http://www.sccmo.org/210/Gateway-Green-Light
[91] St. Louis Regional Freightway. 2017. About. Available at: http://www.thefreightway.com

real-time traffic information, monitoring of real-time traffic and weather conditions, and performance measurement and management activities. [92]

Other Factors

Respondents also indicated a mix of other factors that show promise. Several responses pointed to certain innovation districts in the St. Louis region, such as the Cortex Innovation Community, T-REX innovation building, as well as other corporate research centers. Additionally, the Bi-State Development (BSD) Research Institute, a local non-profit research organization specializing in the evaluation of infrastructure projects, could serve as a valuable resource. The BSD could be a valuable partner in any new transportation pilot projects, as many ongoing technology pilots have opted to partner with local independent research institutes. Survey respondents also eagerly asserted the quality of personnel in the St. Louis region.

Outside research on the topic of ranking regional positioning for technology adoption is minimal, but some evidence points to St. Louis being a strong candidate. A Morgan Stanley report ranked several cities on a scale of 1-10 in terms of their conduciveness to adopting shared mobility services, and found St. Louis to be a 9 on that scale. Their factors for consideration in this analysis were average commute distance, average commute time, population density, and the percentage of local population that commutes alone in personal cars.[93]

Regional Challenges

Complex government structure

Chief among the concerns expressed by survey respondents were the issues posed by a fractured and complex government hierarchy in the St. Louis region. The vast array of different municipal organizations, as well as the bifurcated state authority between Illinois and Missouri, make for a particularly complex governmental structure. When asked if there were unique challenges to technology deployment in the St. Louis region, 37 out of the 68 respondents offering a detailed answer mentioned government disarray and fragmentation as the primary barrier. The patchwork of authorities could stymie any efforts to engage in new or innovative ideas that might require engagement from non-traditional groups of actors. Additionally, any unclear authorities regarding new services could leave projects in jurisdictional limbo, potentially delaying or dissuading investments from private services in the region.

Social and Political Barriers

Survey responses underscored some political and social barriers to technology deployment in the region. Multiple respondents expressed sentiment that the government ought not to have a role in technology deployment, and others suggested that the St. Louis population would not be especially welcoming to multi-modal travel due to the heavily car-centric nature of the region's transportation. People unaccustomed to using transportation modes other than personal automobiles may be less inclined to use alternatives, or perhaps simply less likely to even be aware of them. Research suggests that this is already true with existing shared mobility modes; one study found that usage of many mobility services generally correlated with

[92] EWGCOG. 2015. St. Louis Regional ITS Strategic Deployment Plan and Architecture Report. http://www.ewgateway.org/trans/its/SDPandArchRpt.pdf
[93] Morgan Stanley. 2016. Insight North America. Cities & Shared Mobility – A Policymaker and Investor Guide.

lower rates of car ownership.[94] Other respondents also mentioned crime in the city center as a barrier to technology deployment, both because it competes for funding and because it deters urban density and urban activity.

Within the region, growth has largely been in the suburbs, with population in the city of St. Louis declining since 1950. While the rate of population loss has slowed, population continued to decline in the city from 2010 to 2014, and St. Louis has one of the lowest shares of regional population in the city compared to peer MSAs.

Funding Constraints

Funding for new technology deployments is a challenge nationally, and the St. Louis region is no exception. Lack of funding for new investments was an identified challenge or barrier identified by many survey participants (12 out of the 68 who gave a written answer for the unique barriers question listed funding). Certain technological improvements could involve high up-front costs, such as investments in new electric vehicle or smart infrastructure systems. Others could be much less expensive or reduce on-going operating costs, such as a partnership with private services to operate a ride service to certain destinations and adoption of automation to reduce labor costs in public transportation.

Institutional Readiness

The survey presented a disparity among user attitudes and user preparedness regarding transportation technology. Survey respondents indicated a perception that transportation technology would be highly important both to their organizations operations and to the region as a whole. In fact, virtually all (99.1%) of respondents indicated that it would at least be of “limited importance” to their operations, and 43.9% of respondents said that it would be either “very important” or “extremely important” to their operations. Even more respondents indicated high importance of technology to the region as a whole, with 61.7% saying it would be either “very important” or “extremely important.” Not a single respondent said technology would be “not important,” and only 5.6% thought it would be of “limited importance.”

However, despite the strong sentiment about the importance of technology, organizations indicated low levels of planning around technology. In a question broadly asking about the state of respondents’ planning regarding technology, 36.0% indicated no planning and 54.1% indicated a “limited degree” of planning, compared to only 9.9% of respondents indicating a “significant degree” of planning. When prompted to rank the degree of planning activities undertaken relative to specific technology types, more than half of respondents indicated no planning activities for virtually all technology types.

[94] APTA. 2016. Shared Mobility and the Transformation of Public Transit. Research Analysis. https://www.apta.com/resources/reportsandpublications/Documents/APTA-Shared-Mobility.pdf

6. IMPLICATIONS OF EMERGING TRANSPORTATION TECHNOLOGIES

An important step in determining recommended actions for the St. Louis Region was to gain understanding of the anticipated impacts of technologies on regional goals and on investment needs and priorities.

What are key opportunities and threats to the region from transportation technology?

Impacts on the Region's Guiding Principles

Building on the literature review and interviews with leading experts, the research team conducted an assessment of the expected impacts of emerging transportation technology on the region's Guiding Principles, including likely direction and uncertainty. These impacts represent the opportunities and threats that emerging transportation technology may have on the St. Louis region. A summary of the impacts and their associated uncertainties are illustrated in Figure 5.

Figure 5: Estimated Impacts of Transportation Technologies on EWG's Guiding Principles

(Source: ICF)

The figure provides information on expected direction of impacts, positive and negative (horizontal axis), and the level of (un)certainty with which these impacts can be estimated (vertical axis).

The uncertainty of impacts stems in part from the direct and indirect impacts of technology on outcomes associated with the *Guiding Principles*. **Direct impacts** are those directly addressed by technology. For instance, connected and autonomous vehicle features are expected to have a direct beneficial impacts on

traveler safety through crash avoidance systems and removing driver error and behavioral issues (e.g., distraction, drowsiness, drunk driving). **Indirect impacts** have much higher levels of uncertainty. For instance, while autonomous vehicles may reduce the burden of travel and increase the number and length of trips, enhanced shared mobility alternatives can deter vehicle ownership and therefore reduce overall vehicle travel demand. As a result, impacts on vehicle miles traveled (VMT) are uncertain. It is important to recognize also that impacts on the *Guiding Principles* can be significantly influenced by policies put in place at the national, state, and regional levels, and the role of policy in influencing the direction of the impact is reflected in the lines radiating from each principle as mapped on this diagram.

Positive Impacts / High Certainty

While there are many uncertainties about the future, it is very likely that emerging transportation technologies will have positive effects on certain outcomes, based on what we know today. Specifically, it is anticipated that ***safety*** will improve by removing much of the driver-related factors that are the cause of fatalities and injuries, as several vehicle technologies are designed explicitly to achieve that goal. The overarching safety benefits from technology, particularly AV and CV technology, could be profound. Vehicle automation in particular has been widely lauded as having potential for drastic safety improvements, as 94% of accidents are currently attributed to human error (including distraction, speeding, drowsiness and other behavioral factors that are significant contributors to roadway fatalities and injuries).[95] Additionally, research on V2V connections such as blind spot warnings and lane-change warnings could reduce light-duty vehicle crashes by 76%.[96] The same research also estimated that V2I systems such as stop sign warnings and curve speed warnings could reduce 25% of U.S. light-duty crashes, assuming the systems were deployed in all areas where they could be used. Other vehicle connectivity and big data applications, such as crowdsourced alerts of bad road conditions, could also provide safety benefits through increased situational awareness.

Environmental quality has strong potential for improvement through adoption of clean vehicles, as well as infrastructure that uses solar power or generate energy. Advanced technology vehicles and infrastructure offer the potential for significant reductions in air pollution and greenhouse gas emissions through shifts to electricity and renewable sources of energy such as solar power. Just as vehicle technology and emissions standards have dramatically reduced emissions rates for both automobiles and trucks, further movement to electric vehicles offers potential for significant further emissions reductions and health benefits. One study estimated that if future AVs in 2030 were electric and built smaller, then they could slash per-mile emissions rates by approximately 90% as compared to modern conventional vehicles.[97] Moreover, even without a shift to electricity, AVs may enable fuel efficient braking and acceleration, which could increase fuel efficiency by up to 10-20%.[98] This could be facilitated with both vehicle control and V2I systems that could inform vehicles of traffic light patterns and allow them to plan an efficient course. Other traffic management and connectivity systems enabled by CVs and AVs could reduce emissions by eliminating fuel consumed from traffic congestion, and platooning could reduce emissions from freight. Smart infrastructure could also lower emissions through reduced maintenance activities, specifically those related to snow removal. To foster these effects, however, policies will likely need to play

[95] NHTSA. 2015. Traffic Safety Facts. DOT HS 812 115. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115
[96] Kockelman et al. 2016. Implications of Connected and Automated Vehicles on the Safety and Operations of Roadway Networks: A Final Report. FHWA/TX-16/0-6849-1. http://library.ctr.utexas.edu/ctr-publications/0-6849-1.pdf
[97] Greenblatt, Jeffrey, and Samveg Saxena. 2015. Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles. *Nature Climate Change* 5:860–863. doi:10.1038/nclimate2685
[98] Wadud et al. 2016. Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Transportation Research Part A: Policy and Practice* 86(1):1-18. http://dx.doi.org/10.1016/j.tra.2015.12.001.

an important role, and it is important to recognize the increased vehicle travel could work against these goals.

Intermodal connections, ***transportation choices***, and ***reliability*** of the transportation system are likely to improve due to improved data, routing, and connections among different transportation modes, new travel options such as bicycle sharing and ridesourcing, and improved traffic routing and effective capacity on roadways. It is expected that segments of the population that were previously unable to drive, such as individuals with disabilities, the elderly, and adolescents will now seize their newfound mobility. System reliability will likely be improved through a combination of fewer vehicles crashes, which are a primary source of non-recurring delay, improved real-time information, and advanced routing algorithms.

Mixed Impacts (Positive and Negative) / High Certainty

Technologies are likely to have both some positive and negative impacts on two principles with a fairly high level of certainty. Specifically, technology can help to ***preserve and maintain the existing system*** through advanced infrastructure and detection systems. However, at the same time, improvements in vehicle fuel efficiency and shifts to electric vehicles are likely to adversely affect traditional transportation funding sources (e.g., fuel taxes) and many new technology deployments such as advanced infrastructure will require additional investments and on-going maintenance. Similarly, in relation to ***quality job development***, technology is expected to both result in a decrease in jobs in some fields, such as drivers of buses, taxis, and trucks due to automation, yet offer the potential for jobs in data analytics and other emerging fields as well as in the manufacturing of new products and development of new services. New technology will also likely enable better accessibility to jobs through new transportation service models and modes, particularly for those with current mobility constraints such as persons with disabilities or people without access to private vehicles, although the extent of these benefits depends on affordability. Also, existing travel modes could benefit from reduced operational costs via automation.

Limited or Mixed Impacts / High Uncertainty

The impacts of technologies on ***supporting neighborhoods and communities***, ***supporting public transportation***, and ***fostering a vibrant downtown*** are highly uncertain, with some trends suggesting a positive impact while others suggesting a negative impact. These effects are influenced not only by the marketplace, but may be highly dependent on policy decisions. For instance, automation could significantly reduce transit operations costs on fixed route services, since labor costs are the highest operating costs of public transportation, and technology offers the potential to provide more seamless on-demand connections to transit. At the same time, new services could attract riders away from traditional public transportation.

Equity is another area with uncertain effects. Technologies that reduce transportation costs and enable efficient travel options without owning a private vehicle have potential to increase opportunities for lower-income populations, and the potential for new technologies to enhance equity has been the focus of several federal grant recipient programs. However, without policy incentives, technological advancements may cater more to wealthier populations, which could exacerbate equity and income gaps.

It is important to recognize that even for outcomes that are expected to be positive, there are factors that may negate some of the benefits. Consequently, for most outcomes there are factors that both suggest

positive effects as well as potential negative effects, as show in Table 2. More information on the anticipated effects of emerging technologies on each of the *Guiding Principles* is provided in Appendix B.

Table 2. Summary of Uncertainty Surrounding each Guiding Principle.

Guiding Principle	Factors suggesting positive impacts	Factors suggesting negative impacts
Preserve and Maintain the Existing System	• Use of drones for bridge inspections • Instrumentation of highways to monitor conditions • Pavements that can repair themselves, melt snow, and provide lighted lane striping	• Decline in traditional transportation funding sources through fuel taxes and vehicle registration fees
Support Public Transportation	• Improved transit signal priority, fare collection, and service enhancements • Potential for greater integration with on-demand services that provide first-mile last-mile connections	• Potential for autonomous vehicles, transportation network companies, and other service providers to reduce transit market share
Support Neighborhoods and Communities Throughout the Region	• May provide more access to opportunities for people without access to a private vehicle, as well as disabled and elderly populations	• Technology such as AVs might be primarily for those who can afford it • Potential negative implications of e-commerce on community businesses
Foster a Vibrant Downtown	• Increased shared mobility options could enhance the demand for urban living and working environments • Reduced vehicle and parking demands could provide more space to lower housing cost, add bike lanes, parks, or other amenities	• Reduced time burden of driving due to AVs could encourage more suburban sprawl • Electronic access to health care, education, etc. could reduce benefits of being in the urban core
Provide More Transportation Choices	• Technology enhances alternatives to personal auto use, including bicycle sharing, microtransit, carsharing, and ridesourcing	-
Promote Safety and Security	• CV and AV technology reduces driver error; technologies are designed to reduce crashes, injuries, and fatalities	• Potential concerns about cyber-security in relation to CV and AV technology
Support a Diverse Economy with a Reliable System	• Improvements in monitoring roadway conditions, as well as safety improvements, should directly result in fewer vehicle incidents, which would improve reliability • Better traveler information in vehicles enables travelers to re-route to minimize time stuck in congestion • More vehicle throughput within the existing transportation system that should help to reduce traffic congestion	• Increased VMT could offset some of these benefits.
Support Quality Job Development	• Connectivity has the potential to reduce barriers to travel and facilitate market interaction and overall economic growth. • Opportunities for quality job development in emerging fields, including advanced logistics and data analytics, as well as in the development of innovative technologies and services	• Vehicle automation could reduce direct employment in the transportation sector, as jobs related to driving (everything from truck drivers to taxi and transit service drivers) could be displaced

Strengthen Intermodal Connections	• Opportunities to optimize the supply chain through improved logistics and data sharing are anticipated, resulting in travel time savings • Improvements in passenger connections between modes and services are expected	-
Protect Air Quality and Environmental Assets	• Potential for significant air pollutant and greenhouse gas emissions reductions from shifts to EVs • Potential for clean energy generation throughout roadways, including solar and kinetic energy	• Increased VMT could offset some gains

Key Factors of Uncertainty

Large uncertainties in the direction of impacts of advanced technologies depends on what happens in relation to travel choices/vehicle travel and urban form, as well as public policy decisions.

Vehicle Travel Demand. Impacts on vehicle miles of travel (VMT) from emerging technologies, especially from AVs and shared mobility services, remains a hotly debated topic due to a litany of different competing effects associated with these technologies. Perhaps the most significant factor to consider is the reduced cost of travel from automation, in part because time spent driving is freed to do other activities, and in part because services like TNCs or freight shippers could benefit from reduced driver costs. Additionally, AVs could also induce new vehicle travel from previously underserved groups who are unable to drive, as well as encourage longer trips. A study attempting to estimate the potential VMT increase from these latent demand groups estimated that total U.S. VMT could increase 14% if currently non-driving adults drove as much as average adults in their age cohort.[99] The strength of these effects makes it likely for AVs to induce VMT, all else equal.

Other technologies could work to reduce VMT, such as trends toward shared mobility and reduced vehicle ownership. Most analysts believe that using self-driving fleets will be significantly less expensive than owning a vehicle, which sits idle about 95 percent of the time, ultimately reducing vehicle ownership and putting a price on each trip made. Moreover, since labor is the largest cost associated with operating public transportation services, transit operating costs should also be reduced. Overall, the extent to which new technologies induce VMT will be subject to local policy decisions that will incentivize some travel modes (e.g., transit) and/or technologies/services (e.g., telecommuting) over others. Efforts to implement road pricing or time-adjusted subsidies or fees on certain modes could also provide incentives to curtail VMT.

Land Use and Urban Form. Technology's impact on land use is uncertain, with possibilities ranging from increased urban sprawl to more efficient use of existing space. Many industry observers have speculated that AV technology could have profound impacts on land-use and urban design in the long-term, reducing the need for parking lots for example, with the impacts largely dependent upon the travel and service models for which AVs are deployed (i.e., privately own AVs or mainly shared AVs). Reduced parking could open up land for affordable housing, parks, and others uses, and the ability to squeeze more vehicles into limited road capacity due to automation and advanced safety features could enable more

[99] Harper, Corey D., Chris T. Hendrickson, Sonia Mangones, and Constantine Samaras. 2016. Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions. *Transportation Research and Technology Part C: Emerging Technologies* 72(1):1-9. http://dx.doi.org/10.1016/j.trc.2016.09.003

road space to be turned over to bicycling, walking, or high-capacity transit. On the other hand, continued movements toward digital services, such as e-commerce and telemedicine, as well as AVs may lead to growth in lower density, exurban areas surrounding cities.

Role of Public Policy. While new transportation technologies and mobility services offer potentially significant societal benefits, it should be noted that private sector providers of services have a primary motive of corporate profit rather than advancing social policy goals. Gleaning the greatest social benefit – and equitable distribution of benefits – may require deliberate efforts by policymakers to steer technology deployments in various directions with incentives, partnerships, or regulations. For example, competition between separate mobility companies could result in VMT and congestion increases if these services induce new demand or compete with modes such as walking, biking, and public transit. To alleviate this issue, some experts advocate for congestion or toll pricing, incentives to switch to concurrent sharing algorithms, subsidies for off-peak travel, or even an outright ban of certain technology applications if deemed necessary (such as empty driving of personal autonomous vehicles to go on errands).[100]

As an example, from an environmental (emissions) perspective, the advent of new vehicle service models, combined with varying levels of automation, could catalyze significant changes to vehicle design and usage patterns. Higher vehicle utilization from shared-automated cars (that could essentially drive non-stop), provides an incentive for them to be built with fuel efficient engines and/or electric motors since electricity is generally much cheaper per mile than gasoline. These market trends may lead toward more adoption of clean vehicle technologies. However, these impacts will be shaped by policy decisions at all levels of government. Incentives to use alternative fuels, fuel efficient vehicles, fuel-saving technology (e.g., e-braking or platooning), or efficient service models could play an important role in fostering adoption of these beneficial technologies. Consequently, there should be a strong public interest in influencing the direction of technology deployments to ensure that the public interest is served and that public policy, not just market forces, influences the path forward.

Impacts to Investment Needs and Priorities

One of the most critical issues facing elected decision-makers and those in the transportation planning community relates to how long-range capital investments, and the planning for those investments, should be affected by the presence of emerging technologies. Emerging transportation technologies are anticipated to have important impacts on transportation infrastructure, with corresponding implications for future investment needs. These technology changes could make some investments especially valuable, or render others obsolete. For example, debate continues as to what the preferred method of communication may be between future CVs and their surrounding environment. Investments in DSRC infrastructure could be either a strong choice to spur the proliferation of new CV technology with safety and efficiency benefits, but may not be necessary if vehicles instead become connected with cellular networks. AVs in particular have important consequences for investments in areas of safety, road capacity, and parking developments.

Reduced Needs for New Highway Infrastructure. The additional safety of AVs and their ability to travel closer to one another through connectivity suggests that they may be able to make more efficient use of roadways, essentially boosting capacity. As such, investments to expand capacity might be less valuable than expected. Recent research has even found that these effects could be profound even with very low market adoption levels of AVs; in a study modeling congestion flows on roadways, the inclusion of just one

[100] ICF Expert Interviews, literature reviews.

AV amidst twenty conventional vehicles on a road track proved to garner substantial reductions in the frequency of traffic congestion.[101]

Impacts on Public Transportation Services. Given the uncertainty of impacts of technologies to public transportation, there is significant uncertainty about the value of high-capacity fixed route services, with potential divergent future roles of public transportation in society. Given the commitment of the St. Louis Region to public transportation, as articulated in its Guiding Principles, and desire to support accessibility and a strong urban core, these policy priorities suggest the importance of efforts to integrate technology into public transportation services to enhance its role in the region. The prospect of reducing transit operating costs through automation, for instance, creates the opportunity to redeploy those resources on more service. As noted in a study on the implications of emerging technologies on transit, technology changes also provide an opportunity to substantially restructure the nature of public transportation services themselves. Since part of the motivation for large vehicle sizes is to increase productivity per operator, when unburdened by operator costs, the optimal vehicle size to accommodate passenger volumes and service frequency might favor smaller vehicles running at higher frequencies. Such a service concept might substantially increase the overall appeal of public transportation services. In addition, removing operator costs, coupled with lower operation costs associated with smaller vehicles, would make public transit service more viable for off-peak service times during which large vehicle capacity is unnecessary.[102]

Impacts on ITS Infrastructure. Advanced vehicle technologies, including connected vehicles, will have important implications on ITS infrastructure needs over the long-run, as well as near-term deployments. A study conducted for PennDOT on a Connected and Autonomous Vehicles 2040 Vision noted that "…radio advisories as well as ITS message signs and the way they are designed today will be obsolete in a fully connected environment. Information that currently is available through ITS message signs will be disseminated directly to the vehicles using V2I or V2X technologies and on-board units (OBUs). Cellular technology available today can provide capabilities of sending ITS messages to individuals through smartphone applications. As capabilities of new cellular technologies are expanding, information provided through ITS message signs will become readily available inside vehicles through original equipment manufacturers (OEMs) and on-board units in as early as several years."[103]

Changing Needs Associated with Law Enforcement. The advent of both CV and AV technology could collectively make huge reductions in accident rates. Also, shared-use modes like TNCs, regardless of whether they are automated, could reduce instances of drunk driving. Together, these transportation technologies are highly likely to reduce the need for law enforcement and monitoring of a wide array of behavioral issues, such as red light running, speeding, and impaired or distracted driving, over the long-run. These staff resources could be deployed for improved customer service and to address public safety, potentially supplemented with increased surveillance and data available on passengers to reduce crime on public transportation and within the broader society.

Reduced Parking Needs. Parking needs could also be drastically cut; a study by the International Transport Forum (ITF) modeled the impacts of substituting private car travel for a fleet of ridesharing mini-

[101] Stern, Raphael et al. 2017. Dissipation of stop-and-go waves via control of autonomous vehicles: Field experiments. Available at: https://arxiv.org/pdf/1705.01693.pdf
[102] Polzin, Steven, 2016. *Implications to Public Transportation of Emerging Technologies*. National Center for Transit Research. https://www.nctr.usf.edu/wp-content/uploads/2016/11/Implications-for-Public-Transit-of-Emerging-Technologies-11-1-16.pdf
[103] Carnegie Mellon University, "Connected and Autonomous Vehicles 2040 Vision." Prepared for Pennsylvania Department of Transportation, July 10, 2014.

buses (autonomous or driven) in Lisbon, Portugal, and found that such a fleet could "completely remove the need for on-street parking" and up to 80% of off-street parking.[104]

Workforce Development Needs. The prospect of automated vehicle operation raises the important issue of impacts on the labor force. Driver labor plays an important role in freight movement (i.e., truck drivers), public transportation (e.g., bus drivers, train operators), and other services (e.g., taxis, transportation network companies), and there will be important workforce implications from a shift toward automation. While there is potential for significant reduction in jobs in these industries, there also may be some adjustment of job roles. For instance, some have speculated that rather than entirely eliminating staff, some vehicle driver positions would be redefined as an onboard customer service representative. Across many aspects of the transportation industry, there will be needs to likely develop a smaller but more technology-savvy workforce in order to take advantage of advances in data and technology.

Transportation Funding. Finally, emerging transportation technologies are expected to have significant impacts on the generation of funds through traditional fuel taxes. The primary policy mechanism to generate revenues for road construction and maintenance is the taxing of fuels. These taxes have remained relatively stagnant for many regions for decades, and thus revenues have not been adjusted for inflation, growth in road usage, and increases in construction cost. This challenge is exacerbated by technology advancements leading to improved vehicle fuel economy and an increasing share of electric or hybrid vehicles.

[104] ITF. 2016. Urban Mobility System Upgrade: How shared self-driving cars could change city traffic. ITF, OECD, Corporate Partnership Board. http://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf

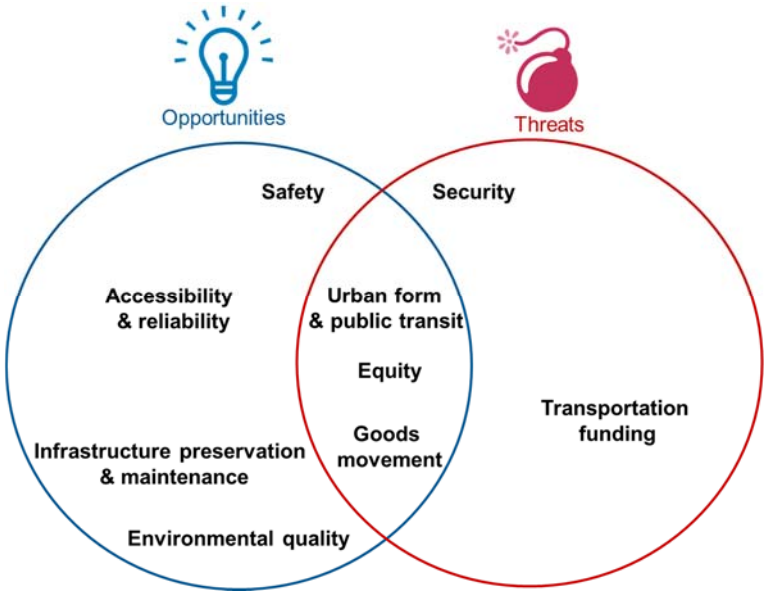
7. POLICY AREAS OF FOCUS IN REGIONAL PLANNING AND INVESTMENT DECISION MAKING

Building on the SWOT analysis, this section recommends areas of focus for policies, programs, and projects to support this Emerging Transportation Technology Strategic Plan's three strategic goals—to harness positive impacts from technology; to address potential negative impacts from technology; and to support the region as a laboratory of innovation.

What policies, programs, and project issues and actions should the St. Louis region focus on in regard to technology and its potential impacts?

These focus area are recommended building off of the assessment of technology opportunities and risks, as shown in Figure 6. Some areas were identified for particularly high potential opportunity, while others have particularly high threats, although it is important to recognize that nearly all of these topics offer some potential for both. Moreover, these areas were identified with a focus on those where policy decisions and investments could play an important role in shaping future outcomes.

Figure 6: Recommended Policy Focus Areas for Regional Planning and Investment Decision Making



These areas of focus should be considered in developing strategies within the regional transportation plan (RTP) and Transportation Improvement Program (TIP). They are recommended for further focus and consideration in relation to state, regional, and local transportation decision-making, including development of policies, programs, and projects by agencies at various levels. For each policy area, various actions are listed that would be likely to have a positive impact in supporting the region's *Guiding Principles*. The recommendations in this section provide ***guidelines to address potential effects of emerging transportation technologies***, as well as ***policy requirements*** or recommendations. While some of these actions might be directly undertaken by EWG staff, many of them would involve other authorities as either

partial or primary actors. In such cases, it is assumed that EWG could spread information and resources in pursuit of enabling such policy development at other agencies.

Safety—*Advancing deployment of safety innovations*

Promote Safety and Security

New and emerging transportation technologies have the potential for dramatic improvements in transportation safety through use of vehicle technologies such as automated braking systems, lane departure warnings, and vehicle collision avoidance systems, as well as through system changes.

Vehicle safety standards are set through federal policy, and the federal government has taken a proactive approach thus far on ensuring safety benefits from AVs—e.g., automated braking systems are likely to be mandated on new vehicles in the near future, and are already present in some vehicles. As noted earlier, since many technologies, such as curb-speed warning vehicle-to-infrastructure (V2I) connections, are designed explicitly with the goal of improving safety, the net impacts of emerging technology on safety are likely to be quite positive.

However, the extent of these benefits to any given region are not guaranteed, and deployment of safety technologies can be advanced by state, regional, and local governments. The St. Louis region should increase efforts to test connected vehicle safety applications in specific contexts, including V2I communications. To maximize safety benefits from new technologies, efforts should be focused on expediting deployment of any proven technologies, and on thoughtful infrastructure investments that integrate new safety features where possible. As AV technology progresses, it may begin to take shape in a range of functions, such as for shared-use applications. It remains to be seen whether safety and operational standards for automated services will be dictated at the federal, state, or local level. EWG and regional partners should watch closely, and note if and how they may best design local regulatory structures.

Survey responses from the St. Louis region highlighted the importance that stakeholders place on safety as a focus for transportation technology policy. Based on survey response, “improving safety” was the highest rated factor that stakeholders suggested be considered in future transportation technology investments, with 95% of respondents indicating this factor is “very important” or “extremely important.”

Table 3 lists some of the policies and actions that EWG can implement to advance the application of technology to improve highway and pedestrian safety.

Table 3. Potential actions to address safety.

Policy Area	Topic	Potential Policies	Responsible Agency
Safety	Crash Avoidance	Invest in V2I communications infrastructure to support safety applications for drivers and pedestrians.	Illinois and Missouri DOTs and local governments
		Consider regional incentives or funding for pilot application of vehicle safety systems.	EWG and local governments
Vehicle Licensing	Vehicle licensing	Make clear determinations of how various vehicle types may operate in a regional transportation network. For instance, will AVs Level 4 be allowed to operate	Illinois and Missouri DOTs and local governments

and Regulations	unmanned or by minors? Will vehicles in shared-use applications be subject to different regulations?

Examples of pilot efforts to demonstrate the readiness of DSRC-based connected vehicle safety applications are on-going. For instance, as part of the Federal Connected Vehicle Pilot Program (CV Pilot Program), the Wyoming Department of Transportation (WYDOT) is developing applications that use V2I and vehicle to vehicle (V2V) connectivity to support safety on the I-80 corridor, which is a major corridor for east/west freight movement that experiences wind speeds and wind gusts exceeding 30 mph and 65 mph respectively during winter months. A flexible range of services from advisories including roadside alerts, parking notifications and dynamic travel guidance is being deployed to reduce the number of blowover incidents and adverse weather related incidents (including secondary incidents) in the corridor.[105] Other pilot locations include New York City, NY and Tampa, FL. As part of its innovative Road X program, Colorado DOT has partnered with Panasonic to build an ecosystem for connected transportation where smart vehicles, self-driving vehicles, and infrastructure share instantaneous data and information about road and safety conditions in order to reduce crashes and increase effective roadway capacity.[106] In the CV Pilot Program, a major focus is on program evaluation so as to inform broader future efforts, whereas the RoadX program is meant to be far-reaching and have substantial impact within the next decade. Both programs are still in early phases. Similar investments in piloting safety technology advancements could be made in the St. Louis Region.

Security—*Ensuring data privacy and cybersecurity*


Promote Safety and Security

At the same time that transportation technologies offer great potential for roadway safety improvements, agencies also need to consider the safety and security aspects associated with the development and operation of new technologies that involve automation and in the handling of private information due to possibilities associated cyber-security breaches. Vehicle, mobile, and web applications, as well as infrastructure technology (e.g. Internet of Things, AI Technology) that uses connectivity, may be subject to cyber threats. Table 4 lists some of the policies and actions that EWG can implement to ensure the efficient and secure management of information.

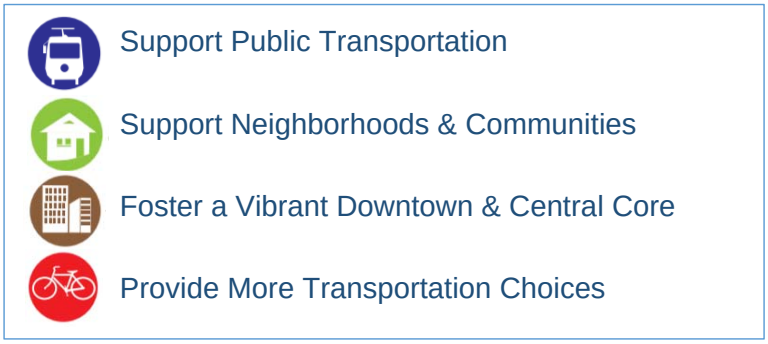
Table 4. Potential actions to address privacy and security.

Policy Area	Topic	Potential Policies	Responsible Agency
Information Management	Privacy	Consider adopting standards to ensure systems and technologies incorporate data privacy, specifically those related to personally identifiable information (PII). This is especially important in the context of increased collection and reporting of data.	Illinois and Missouri DOTs and local governments
	Cybersecurity	Support funding to increase investment in cybersecurity of transportation networks, particularly as new technology is deployed.	Illinois and Missouri DOTs and local governments

[105] ITS Joint Program Office. 2016. "Connected Vehicle Pilot Deployment Program." http://www.its.dot.gov/pilots/
[106] Colorado Department of Transportation. "Road X: Projects in Motion." https://www.codot.gov/programs/roadx/projects-in-motion

Federal agencies and private entities have developed guidance to catalog security and privacy controls for information systems and a process for selecting controls to protect operations, assets, and individuals from threats including hostile cyber-attacks, natural disasters, structural failures, and human errors (both intentional and unintentional). Examples of these guidance are the National Institute of Science and Technology's *Security and Privacy Controls for Federal Information Systems and Organizations,*[107] SAE's *On-Board System Requirements for V2V Safety Communications J2945/1*,[108] and FHWA's *Connected Vehicle Data Capture and Management (DCM)*[109] and *Dynamic Mobility Applications (DMA).*[110]

Urban Form and Public Transit—*Fostering policies that address the threats of increased decentralization due to technology and harness the advantages to support a vibrant central core and public transportation*



While the St. Louis region benefits from its robust public transportation network and has implemented service improvements (including new articulated buses and construction of a new CORTEX MetroLink station), the St. Louis region ranks below average among peer regions on measures of transit, such as percentage of jobs and workers residing in areas that have access to transit. Similarly, St. Louis ranks below average among peer regions with regards to employment in the central business district, due to a declining share of employment in the central core. Moreover, population in the region's central core has declined since the 1950s, as both residential development and employment have moved outward.[111]

As noted earlier, the impacts of emerging technologies on both transit and land use are highly uncertain; several technologies can be applied to public transportation systems and are likely to support transit use, but others, particularly autonomous vehicles (AVs) and mobility-on-demand (MOD) services like TNCs, could compete with it and induce VMT, congestion and sprawl. Conversely, AVs and MOD services also could reduce the need for parking in urban areas, creating the potential to repurpose on-street parking for other functions, including loading/unloading zones for freight/package delivery, bicycle/pedestrian infrastructure, or parks.

Transportation policies and investments will likely be a key determinant in whether new mobility services and automation are harnessed to supplement and improve the public transit system, or instead to compete with it. The convenience of these new technologies will bring large accessibility benefits, but may also induce congestion and reduce transit ridership unless policies are enacted to mitigate those effects.

[107] Accessible at: http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-53r4.pdf
[108] Available at: http://standards.sae.org/j2945/1_201603/
[109] Available at: https://www.its.dot.gov/research_archives/data_capture/index.htm
[110] Accessible at: https://www.its.dot.gov/research_archives/dma/index.htm
[111] East-West Gateway Council of Governments. July 2015. "Where we Stand: The Strategic Assessment of the St. Louis Region." http://www.ewgateway.org/WWS/wws.htm

Table 5 summarizes potential policies and actions related to shaping urban form and supporting transit.

Table 5. Potential actions to support transit and urban vitality.

Policy Area	Topic	Potential Action	Responsible Agency
Public Space and Urban Design	Public street space	Provide guidance to local governments, including downtown St. Louis, on public street space, including optimal mix of space for on-street parking, shared use options, and transit services, given new transportation service options.	Local governments
	Zoning, urban design, and parking requirements	Encourage local governments to consider new zoning requirement for development that reflect reduced needs for parking for privately owned vehicles, more use of shared vehicles, and other technology-enabled options.	Local governments
Land Use / Urban Form	Land use planning	Advance regional and local land use policies to encourage development of downtown areas and regional activity centers linked through public transportation (i.e., dense transit oriented development), recognizing in particular the potential for transportation technologies to encourage decentralization.	Local governments
		Support incentives and policies to encourage density in transit oriented locations, tied to use of technology to enhance transit, such as reducing parking requirements for residential and commercial buildings in downtown areas.	Local governments
Transit	Support fixed route transit	Support public transit through pilot initiatives that deploy new technologies to provide better first-mile last-mile access to transit, such as autonomous shuttles or bikesharing.	Metro
		Integrate fare payments with other services so as to facilitate multi-modal travel options modes	Metro
		Develop pick-up and drop-off spaces in key areas, such as rail stations, to facilitate ridesharing.	Metro
		Consider incentives or fees on mobility services geared at maximizing their linkages with high-capacity transit	Metro
	Service efficiency and quality	Advance automation in public transportation and quality improvements (e.g. free Wi-Fi.) through pilot programs to assess impacts on efficiency and costs of providing service.	Metro
		Incorporate improvements in the availability of the real-time travel information for public transportation and more accessible fare payment options.	Metro

		Integrate strategies such as transit signal priority into arterial improvements.	Metro
New Mobility Services	Encourage multi-modal lifestyles	Establish clear and fair rules for operating mobility services such as ridesharing, carsharing, and microtransit systems, so as to reduce the burden of operating those services in the region.	Local governments and Metro
		Designate "mobility hubs" where several modes, such as biking, walking, ridesharing, and public transit can all intersect.	Local governments and Metro
	Mobility-on-demand policies	Create options for residential buildings to provide mobility packages in place of parking spaces to new residents.	Local governments and Metro

In order to realize the more positive potential impacts, several strategies to integrate public transportation with other modes could be considered. Different transportation agencies across the nation have begun experimenting with policies such as **targeted subsidies of MOD rides** to and from transit stations.[112] For instance, based on an public-private partnership agreement between Uber and the Pinellas County Transit Authority (PSTA) designed to support "first mile-last mile" connections, users of Uber open the "Uber PSTA" option on the app to receive a ride to or from PSTA public transit bus stops at a subsidized price. Many agency-TNC partnerships have recently been formed to advance inter-modal connectivity, and further discussion on these partnerships and how similar ones could be formed in the St. Louis region is presented in Section 8. Other partnerships leveraging TNCs for first/last mile connections include:

- A program by the City of Centennial, Colorado with Lyft and Via Mobility Services ("GoCentennial") designed to improve rail access to travelers, particularly elderly folks, by offering free Lyft Line rides to and from key transit stops.[113] The pilot program concluded in early 2017, but is being reviewed for a possible expansion.[114]
- A City of Summit, NJ effort offers door-to-door service via Uber rides to commuters in place of adding additional parking; the program was designed to alleviate parking demand at a much lower cost.[115] City officials indicate that the program cost $167,000 per year, much less than an estimated $10 million required for a new parking lot.[116]
- A partnership between the Greater Dayton Regional Transportation Authority (RTA) and Lyft to extent transit access to rural customers. The program works by offering discounted Lyft rides to and from key bus stops that connect to the broader bus network. Customers can order discounted rides through the Lyft app of by calling the RTA call center.[117]

Additionally, transit agencies can take lessons from private mobility companies about how to attract riders, such as the importance of reducing the stress of travel through the **inclusion of accurate real-time arrival**

[112] See, for example: Pinellas Suncoast Transit Authority Press Release. October, 26, 2016. https://www.psta.net/about-psta/press-releases/2016/psta-expands-transit-partnership-with-uber-lyft-across-pinellas-county/
[113] City of Centennial, CO. GO Centennial Pilot Program Overview. http://go.centennialco.gov/
[114] City of Centennial, CO. GO Centennial Pilot Program February Report. http://siteassets.pagecloud.com/flmp/downloads/GoCentennialReport_Feb_1-ID-d7e0da4f-dc4a-4a5d-871c-e8db9366d1aa.pdf
[115] City of Summit, NJ. Summit's New Uber Ridesharing Program for Resident Commuters. https://www.cityofsummit.org/CivicSend/ViewMessage/message?id=25285
[116] Anand, Priya. 2016. How uber plans to conquer the suburbs. Buzzfeed News. *Available at:* https://www.buzzfeed.com/priya/how-uber-plans-to-conquer-the-suburbs?utm_term=.nhJae9z47#.quRREAmjL
[117] Dayton RTA. 2017. RTA expands options with new RTA Connect service. May 17, 2017 press release. *Available at*: http://www.i-riderta.org/news/rta-expands-options-with-new-rta-connect-service

information and simplified fare payment. As an example of the latter, NYC is currently testing a system that would allow transit riders to simply touch their smartphones or bank cards against an electronic reader, rather than having to purchase a separate fare card for the metro system.[118]

While the industry focus on automation in vehicles has been predominantly focused on personal vehicles and trucks due to the massive global market potential, **automation in public transit** offers many potential benefits given the high share of transit operating costs associated with labor. In addition, the institutional environment of public transportation, the high use and exposure of public transit vehicles, and the professional operator and maintenance environment could make them attractive test-beds for automation pilots. They often operate in urban environments with high interaction/risk opportunities with other vehicles, pedestrians, and bicyclists and typically carry passenger volumes several times higher than an average automobile, making them attractive and appropriate laboratories for early deployment opportunities for safety-enhancing vehicle technologies, particularly given federal requirements focused on public transportation safety. [119]

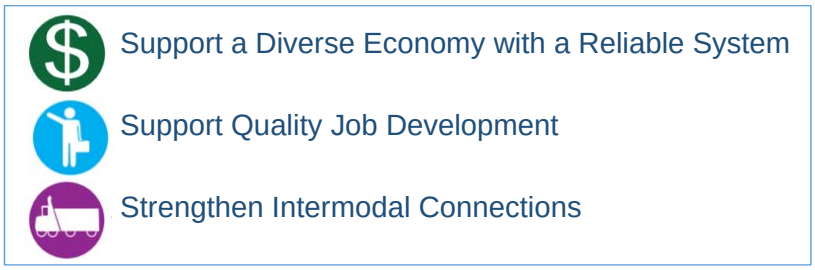
Governments can also use **policies pertaining to public street space**, such as optimizing their mix of curb space, parking, and transit. With the advent of new cheap point-to-point ride services, the importance of downtown parking might diminish relative to drop-off zones. Already, special pickup and drop-off areas for mobility service rides have been designated at sports stadiums[120] and airports.[121] Portland, OR, developed the "Option Zone," which is a carsharing parking space designated by an orange pole and attached bicycle rack that can be mounted to parking meter heads and curbs.[122] Efforts to improve curb space management via sensors, dynamic reservations, and other technologies, could improve freight delivery, and consequently general use of public space. Additionally, the shift towards more on-demand mobility may reduce the need for parking at downtown residencies. In San Francisco, an apartment complex opted for a small amount of parking and instead partnered with Uber to issue residents a $100 monthly stipend for all transportation, including subsidized Uber rides.[123] Cities could take approaches to **reduce parking requirements**, and instead encourage developments to offer similar deals. For instance, the City of Evanston, a north Chicago suburb, maintains a carsharing parking reduction clause in its zoning code. The code permits a reduction in the minimum number of required parking spaces for projects that provide at least one on-site carsharing parking space.[124]

While not directly tied to planning for technology, a number of MPOs have gained regional consensus with local jurisdictions to support **planning that encourages development in mixed use activity centers with high quality transit**. For instance, in the Washington, DC region, the Metropolitan Washington Council of Governments (MWCOG) works with local governments to help support land use planning by analyzing growth and informing leaders and stakeholders on placemaking. The *Region Forward Vision* emphasizes

[118] Schaller Consulting. 2017. Unsustainable? The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City. *Available at:* http://www.schallerconsult.com/rideservices/unsustainable.pdf
[119] Polzin, Steven, 2016. *Implications to Public Transportation of Emerging Technologies*. National Center for Transit Research. https://www.nctr.usf.edu/wp-content/uploads/2016/11/Implications-for-Public-Transit-of-Emerging-Technologies-11-1-16.pdf
[120] Lutz, Meris. 2017. Braves announce Uber, Waze partnerships as part of traffic plan for new stadium. *The Atlanta Journal-Constitution*. http://www.ajc.com/news/local-govt--politics/braves-announce-uber-waze-partnerships-part-traffic-plan-for-new-stadium/9pD2Znds2RYVtMPh3JrruL/
[121] See, for example: http://www.miamiherald.com/news/local/community/miami-dade/article77973802.html
[122] FHWA, 2016. *Shared Mobility: Current Practices and Guiding Principles.* https://ops.fhwa.dot.gov/publications/fhwahop16022/fhwahop16022.pdf
[123] Hawkins, Andrew. 2016. Uber and a Bay Area landlord will pay new tenants $100 a month to go car-free. *The Verge*. https://www.theverge.com/2016/5/18/11691904/uber-parkmerced-maximus-real-estate-stipend-san-francisco
[124] FHWA, 2016. *Shared Mobility: Current Practices and Guiding Principles.* https://ops.fhwa.dot.gov/publications/fhwahop16022/fhwahop16022.pdf

activity centers for accommodating future growth, and MWCOG provides tools to assist local governments and other regional stakeholders in strengthening their centers.[125] Similarly, the Atlanta Regional Commission (ARC) has funded *The Livable Centers Initiative* (LCI), which is a program that awards planning grants on a competitive basis to local governments and nonprofit organizations to prepare and implement plans for the enhancement of existing centers and corridors consistent with regional development policies, and provides transportation infrastructure funding for projects identified in the LCI plans.[126]

Reliability of the Transportation System—*Using technology to improve access to real-time traveler information and optimize system reliability*



Commuters and businesses alike recognize the importance of ensuring a reliable system that effectively manages delays from both recurring congestion and nonrecurring events, such as adverse weather conditions, incidents, and special events. Currently, the St. Louis region, when compared to peer regions around the country, does not experience serious congestion, and so reliable system operations to address nonrecurring delays is of higher priority when compared to recurring congestion.[127] Nonetheless, it is important to note that while many emerging technologies are being designed explicitly to fill transportation information gaps, improve system reliability, and reduce congestion, the reduced costs of travel and increased use of autonomous vehicles could upsurge vehicle travel on the network and potentially increase traffic congestion.

Recommendations for the region in this area include deploying strategies to **take advantage of new technologies to improve reliability and travel times**, while **reducing the potential for growing vehicle travel demand**, as well as **improving user's access to information**. The St. Louis region has already taken important actions related to the former by implementing real-time location website information for its Metro transit systems, and creating a downloadable smartphone application. As technology advances, investments in ITS infrastructure also will need to account for the growing role of private sector data and evolving roles of the public sector in traveler information and other functions, which should be reflected in future ITS plans. For instance, many regions are already re-thinking their use of 511 systems and are partnering with private sector companies to provide real-time travel information to the public. In developing the Regional Multi-Modal Traveler Information System and Journey Planner as outlined in the ITS Architecture document, EWG should consider whether it is more costly to develop it from scratch, or to partner with a private organization already offering similar services, and to expand or tweak the service as necessary to meet expectations for accessibility and coverage.

Changes in investment decisions and priorities are also expected, including potential for less new highway capacity as a result of technology squeezing more capacity out of the existing transportation system, which needs to be accounted for in future investment planning. Applications that give real-time traffic and routing

[125] Metropolitan Washington Council of Governments, "Activity Centers" https://www.mwcog.org/community/planning-areas/land-use-and-activity-centers/activity-centers/
[126] Atlanta Regional Commission, "Livable Centers Initiative." http://www.atlantaregional.com/land-use/livable-centers-initiative
[127] East-West Gateway Council of Governments. July 2015. "Where we Stand: The Strategic Assessment of the St. Louis Region." http://www.ewgateway.org/WWS/wws.htm

information are increasingly prevalent, and autonomous vehicles could leverage this data to readjust routes and maximize system efficiency. New technology also expands the options for collecting data on traffic flow patterns with which to plan investments. Table 6 lists potential policies and actions related to mobility and reliability.

Table 6. Potential actions to improve mobility and reliability.

Policy Area	Topic	Potential Actions	Responsible Agency
System Management and Operations	ITS needs	Evolve ITS and congestion management planning in the region to integrate and adjust technology applications as vehicle technologies continue to advance.	Illinois and Missouri DOTs and local governments
	Active system management	Implement active system management strategies, such as Integrated Corridor Management, leveraging technologies. Active management also includes improved regional operational collaboration and systems to optimize performance.	Illinois and Missouri DOTs and local governments
	Infrastructure capacity and needs	Identify potential changes in infrastructure, such as reduced lane widths, opportunities for dynamic use of shoulders, and other strategies. Explore and consider the future potential for development of AV-designated lanes (especially if technology plateaus such that AVs can only operate in certain conditions), truck-only lanes, and other infrastructure-related changes to support technologies that improve safety and reliability, and to incentivize use of advanced vehicle technologies.	Illinois and Missouri DOTs and local governments
	Data sharing	Ensure data feeds are provided to help the private sector and the public have access to real-time information. Provide support for real-time Application Programming Interfaces (APIs), and standardization of data feeds (like GTFS - General Transit Feed Specification, TMDD - Traffic Management Data Dictionary).	Illinois and Missouri DOTs, Metro and local governments
Demand Management	HOV and non-motorized travel	Consider policies to reduce vehicle travel leveraging technology, such as road pricing, or toll or parking credits for using higher occupancy vehicles, or shared ride services [These policies can be integrated into a broader strategy for transportation infrastructure funding].	Illinois and Missouri DOTs and local governments
	Off-peak deliveries and travel	Consider policies, such as financial incentives, to encourage travel to be done at off-peak time periods, particularly for large-scale freight and package deliveries	Illinois and Missouri DOTs and local governments

Equity—*Using technology to enhance connections for underserved communities and ensuring that technology-based services don't bypass disadvantaged communities*

Support Neighborhoods & Communities

Emerging transportation technologies offer an array of options for improving access to goods, services, jobs, and spaces. Communication technologies via the internet allow for access without mobility, while new vehicle technologies improve the range of options to travelers and reduce barriers to multi-modal trips. While the advent of new technologies all but ensures that accessibility will improve overall, some groups could be left out, especially lower-income and minority populations. Among its peer regions, the St. Louis region ranks among the 10 regions with the largest disparities between blacks and whites on infant mortality, poverty, and unemployment.[128] These regional disparities speak to the important potential role of transportation technology advances (together with education, housing, and other policies) to help support equitable access to opportunities.

Public agencies can play an important role in ensuring that technology improvements are harnessed to benefit all population groups, particularly those in disadvantaged communities. In some cases, this will mean tweaking existing public transportation services, or **contracting private services** to serve certain neighborhoods or act as an extension of transit for off-peak hours. As an example of the latter, a community in Florida has begun subsidizing Uber and taxi rides at late hours of the night to allow lower income workers to return home after working later shifts.[129] Because the local bus services do not operate late at night, this essentially serves as an extension of the bus system, allowing these low-income workers to have public transportation available for all of their commuting needs. Since private mobility services often solicit payments exclusively through a smartphone application tied to a credit card, such partnerships might need additional care to ensure access to all. In the case of the Uber partnership in Florida for late night workers, a local taxi company was also included, which ensured that there was an option for all folks. While TNCs may not be inclined to develop their own technological solutions to these issue of payment and access, they have done so in certain circumstances. For example, Uber has previously made kiosks from which people can order rides in special situations, such as at large music festivals and at a bars in an effort to curb drunk driving. Regional partners could work with private services to either develop the technological solutions allowing for payment through other means, or as in other cases, simply also partner with companies that can assure complete accessibility.

Emerging technologies have also shown potential to improve accessibility and service quality for disabled populations. For example, the Massachusetts Bay Transportation Authority (MBTA) partnered with Uber and Lyft to reduce paratransit costs and improve service by allowing users to have the option to order rides via these services in addition to the vehicles serving under its traditional service, "The Ride."[130] The customers benefit from immediate service, as opposed to the scheduled next-day service provided through their default paratransit options. In addition, the program is estimated to have saved the agency roughly $40,000 and reduced customer fares.[131] New CV technologies can also assist visually impaired

[128] East-West Gateway Council of Governments. July 2015. "Where we Stand: The Strategic Assessment of the St. Louis Region." http://www.ewgateway.org/WWS/wws.htm
[129] PSTA Press Release. July 20, 2016. http://www.psta.net/press/07-2016/index.php
[130] Massachusetts Bay Transportation Authority. On-Demand Paratransit Pilot Program. http://www.mbta.com/riding_the_t/accessible_services/default.asp?id=6442456760#How_it_works
[131] Bankson, Amy. 2017. MIT Sloan Newsroom. http://mitsloan.mit.edu/newsroom/articles/uber-and-lyft-partner-with-boston-transit-agency-to-provide-on-demand-rides-to-disabled-residents/

pedestrians. For example, the New York City CV Pilot program plans to implement a system that would leverage the smartphones of visually impaired pedestrians to warn nearby drivers. [132]

Emerging technologies can be targeted or piloted in underserved communities to help more flexibly connect people to jobs, health care, and other services. For instance, Columbus proposed the development of a new autonomous shuttle service serving lower income residents as part of its winning proposal for the U.S. DOT Smart City Challenge. Other measures targeting equity in the Columbus proposal include a smartphone application with assistance for people with disabilities, and the inclusion of kiosks (in addition to an online platform) for payment to the new Bus Rapid Transit (BRT) system. EWG and regional partners should consider both small-scale improvements, such as support allowing visually impaired people to cross streets, as well as larger and more costly improvements, such as development of new services or major augmentations to the transit system that are targeted at a previously underserved or disadvantaged group.

Table 7 lists potential actions and policies addressing issues of accessibility and equity.

Table 7. Potential actions to ensure accessibility and equity.

Policy Area	Topic	Potential Policy	Responsible Agency
Accessibility and Equity	Accessibility	Pilot test or promote policies such as providing alternative payment methods for mobile payment services. Ensure that new services and technology are accessible to all, including those who do not have access to e-payments linked to credit cards and/or bank accounts.	Metro and local governments
	Non-discrimination	Implement policies to ensure that new private-sector services provide fair and equitable access across all sectors of the population; this may include requirements to meet American with Disabilities Act (ADA) standards as well as Title VI in relation to service provision and service changes.	Metro and local governments
	Coverage	Offer incentives for private services to provide their services in marginalized areas, such as those with predominately low-income population.	Metro and local governments
	Subsidies	Provide subsidies for new technologies and transportation services to target connecting specific areas location of interest (e.g., job districts, hospitals, or schools) or to continue services after low demand hours (e.g., late-night ride home subsidy programs) to meet the needs of low-income and disadvantaged populations.	Illinois and Missouri DOTs, Metro and local governments

[132] For an example of this being done with CV technology, see: DOT. 2016. CV Pilot Deployment Program, New York City. Concept of Operations. https://ntl.bts.gov/lib/59000/59300/59360/FHWA-JPO-16-299.pdf

Freight and Logistics—*Using technology to enhance efficient goods movement and spur economic development*

Support Quality Job Development

Strengthen Intermodal Connections

As an important freight hub, the St. Louis region can benefit from technology advancements and targeted investments to help support the efficient movement of goods. As noted earlier, emerging technologies have potential improve the efficiency of the freight system through innovations at both the vehicle and system level. Already, governments have taken a variety of approaches to harness new technologies to benefit freight shipment in their jurisdiction. Federal grant programs such as the Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Program have spurred some technology-focused freight improvements. For example, the Denver ATCMTD program includes outfitting 1,500 city vehicles to facilitate platooning between vehicles and right of way signaling in key corridors.[133] The Niagara-Buffalo ATCMTD Program aims to improve overall freight efficiency by providing real-time information on traffic, parking, and weather conditions to commercial freight drivers.[134]

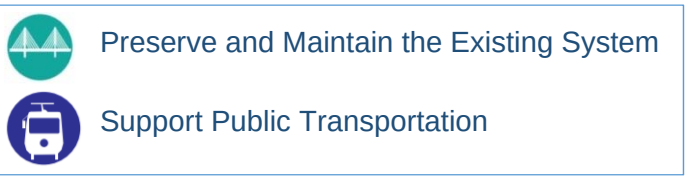
Freight shipping efficiency improvement from algorithm and matching changes are likely to be driven by the private sector, as many applications aiming to do so are already rapidly proliferating in the market. However, governments can make some improvements of their own, such as engaging in efforts to improve curb space management via sensors, dynamic reservations, and other technologies, could improve freight delivery. Additionally, if freight travel safety improves either via automation and connectivity, then perhaps weight limits for freight vehicles could also be increased, allowing for more goods to be shipped in less vehicles.[135]

Policy Area	Topic	Potential Action	Responsible Agency
Efficient shipping and routing	Key corridors	Prioritize freight corridors when outfitting roads with necessary CV/AV technologies	Illinois and Missouri DOTs, Metro and local governments
	Curb space management	Improve curb space management via sensors, dynamic reservations, and other technologies	Local governments
Inter-modal connections	Data sharing and management	Facilitate the centralization of data for freight shipment across modes (air, road, rail, and marine) to optimize decision-making across stakeholders. This entails the inclusion of freight agencies (public and private) in Integrated Corridor Management strategies and the development of freight-specific portals of communication.	Illinois and Missouri DOTs and local governments
	Truck parking	Provide truckers with real-time information on parking availability and truck routes	Illinois and Missouri DOTs

[133] FHWA. Oct 13, 2016 Press Release. USDOT announces $6 million grant for Denver's Smart City Program. https://www.fhwa.dot.gov/pressroom/fhwa1651_denver.cfm
[134] FHWA. Oct 13, 2016 Press Release. USDOT announces $7.8 million grant for border crossing technologies in Niagara-Buffalo region. https://www.fhwa.dot.gov/pressroom/fhwa1651_niagarabuffalo.cfm
[135] This was suggested during the ICF Expert Interviews, though it should be noted that there are other factors determining truck weight limits, such as infrastructure strain.

Drones	Operating regulations	Remain appraised of Federal Aviation Administration and Department of Transportation rules about the use of the air space by drones. Establish clear policies on drone usage on the basis of safety, noise, privacy, and other considerations.	Illinois and Missouri DOTs and local governments
Pilot testing and research	Pilot Testing	Cooperate in tests of autonomous and connected vehicle technology for freight systems by having a clear process for permitting pilot programs and tests.	Illinois and Missouri DOTs and local governments
	Alternate Modes	Review the research priorities to promote qualitative and quantitative assessment of alternate modes of freight transportation, such as Hyperloop and Freight Shuttle systems.	Illinois and Missouri DOTs and local governments

Infrastructure Preservation and Maintenance—*Applying technology to improve the monitoring of infrastructure conditions and strengthen asset management*



The state of Illinois ranks first in terms of percentage of the road system in poor or mediocre state of repair (73%), while for the state of Missouri, this measure is 31%. This poor level of condition translates into an estimated annual aggregate additional cost to Illinois and Missouri drivers for vehicle repairs and operating costs of $2.4 billion and $1.6 billion, respectively.[136] Finding the financing mechanisms to bring roads and bridges to an acceptable state of repair proves extremely challenging. For example, Illinois Senate Bill 3279 in 2016 proposed a 30-cent increase in the motor vehicle fuel tax. Thus identifying ways in which technology can help with this problem promises to yield big returns.

New technologies offer the potential to **enhance the efficiency and effectiveness of infrastructure preservation and maintenance** through advanced and continuous monitoring, maintaining, and preserving infrastructure. For instance, LiDAR has been increasingly utilized for aerial and terrestrial scanning in myriad applications. The projected dramatic reductions in cost of LiDAR sensors and supporting technologies (data storage, etc.) is making possible for sensors to be increasingly deployed in vehicles, primarily to support automation.[137] This creates the potential for sensors of extremely high resolution to be virtually ubiquitous, and consequently highly improve collecting data on road infrastructure. Use of drones can support more effective bridge inspections, and technology offers the potential for pavements that are instrumented to monitor conditions, as well as potentially to melt snow and repair themselves.

AVs, could impact both total VMT, as well as travel flow patterns. Roadways may have an effective capacity increase from AVs, and therefore the rate of degradation may increase. Moreover, patterns of travel may change, such as having more vehicles travel over the exact same pavement area within the roadway surface, rather than slight variations, which may cause more or different wear patterns on pavements. Additionally, if combined with mobility services, travel patterns could shift substantially, and vehicle types could also alter. In the long-term, if cars were to be used largely in shared-use, high-utilization applications,

[136] U.S. Department of Transportation: https://www.transportation.gov/policy-initiatives/grow-america/road-and-bridge-data-state
[137] While LiDAR is the dominant and most developed technology for autonomous vehicle applications, there are competing technologies, such as coherent optical radar, that could offer better performance and lower costs.

they would be likely to be built lighter, reducing strain on roads. The extent to which effects will dominate is uncertain, but these impacts could warrant adjustments to roadway preservation protocols.

The regional survey of stakeholders highlighted "state of good repair" as a key factor to consider in future transportation technology investments (second highest rated, only behind safety), with 83% of respondents indicating it is a "very important" or "extremely important" factor to consider in technology investments. Table 8 lists potential policies and actions related to infrastructure preservation and maintenance.

Table 8. Potential actions to support infrastructure preservation/maintenance.

Policy Area	Topic	Potential Action	Responsible Agency
Infrastructure Preservation and Maintenance	Conditions monitoring	Evaluate the use of advanced technologies to support monitoring conditions, including potential for use of drones and vehicle-generated data.	Illinois and Missouri DOTs, Metro and local governments
	Investments	Work with State DOT partners to explore use of new technology within the physical infrastructure itself, such as use of advanced pavements and integration of communications technology in infrastructure. Build on research programs and pilot deployments available from the U.S. Department of Transportation.	Illinois and Missouri DOTs, Metro and local governments

Funding—*Addressing the challenge of limited revenues for transportation investment and maintenance*

Preserve and Maintain the Existing System

Support Public Transportation

While transportation funding will be a challenge nationally, it is important for the St. Louis region to consider regional and local implications and alternate possibilities for funding sources. As advanced vehicle technologies that reduce vehicle fuel consumption per mile through shifts to electric or other alternative vehicles take place, it will likely be important for the St. Louis region to consider funding implications in its long-range fiscal planning.

At the same time, technologies offer new possibilities for road mileage-based fees and other user-fee payment structures. Some governments have already opted to levy new fees on MOD services like Uber and Lyft. For example, Georgia recently passed HB 225 which stipulated a sales tax on ridesharing app services, with some of the funds going towards state and local municipalities.[138] While not directly tied to technology planning, several regions also have begun to analyze and consider the potential for mileage-based fees. For instance, the Puget Sound Regional Council (PSRC), the MPO for the Seattle region, created a Pricing Task Force as part of the update process for its long-range plan called Transportation 2040, which was adopted in May 2010, recognizing the potential role that pricing might play in the long term both as a revenue source and to modify travel behavior. The plan recommended a phased financial strategy that moves toward the implementation of new user fees, including tolls, exploration of a fuel tax

[138] Georgia House Bill 225. http://www.legis.ga.gov/Legislation/20172018/167145.pdf

replacement, such as vehicle- miles traveled (VMT) charges, and other pricing approaches to fund and manage the transportation system.[139] Many of the regions that have explored road and congestion pricing are more heavily congested than the St. Louis region, and so the incentives for congestion reduction will not be strong in the St. Louis region. However, there have been successful efforts to approve State or regional funding mechanisms for transportation, which can be a model.

Other governments have also turned to TNCs as a means to reduce the costs of providing transit. The previously mentioned partnerships by MBTA, PSTA, and the City of Summit all resulted in cost reductions to provide services by swapping low-occupancy or otherwise costly routes for TNC subsidies. One small Canadian town took this to the extreme by opting to forego conventional public transportation altogether and simply offer subsidized Uber rides to the public, claiming that it would be the most cost-effective option for providing transportation.[140]

Table 9 lists potential policies and actions related to infrastructure funding.

Table 9. Potential actions to support infrastructure funding.

Policy Area	Topic	Potential Action	Responsible Agency
Funding	New revenue sources	Identify and develop regional consensus on new sources of revenue to support transportation infrastructure preservation, maintenance, and operations beyond traditional transportation sources (e.g., gas tax). This may include consideration of mileage-based fees or other user fees.	Illinois and Missouri DOTs and local governments
		Create new fee structures for ride services, such as has been done in Georgia and Massachusetts.[141]	Illinois and Missouri DOTs and Metro
		Consider opportunities for partnering with private mobility companies to reduce operational costs	Metro

Environmental Quality—*Advancing the adoption of eco-friendly infrastructure and vehicles*

Protect Air Quality and Environmental Assets

Many emerging technologies have unequivocal potential for significant positive environmental impacts, such as electric vehicles (EV), and logistics software for smarter trip planning. Other technologies with positive effects include eco-driving and vehicle platooning (especially in freight), which are closely related to the development of autonomous driving technology. AVs may not necessarily be entirely beneficial to environmental quality given their potential to induce VMT. While there is reason to believe that market

[139] FHWA, 2011. "Congestion Pricing – A Primer: Metropolitan Planning Organization Case Studies." https://ops.fhwa.dot.gov/publications/fhwahop11030/cm_primer_cs.htm
[140] Smith, Craig. 2017. A Canadian town wanted a transit system. It hired Uber. https://www.nytimes.com/2017/05/16/world/canada/a-canadian-town-wanted-a-transit-system-it-hired-uber.html?_r=0
[141] Hawkins, Andrew. 2016. Massachusetts becomes the first state to tax Uber and Lyft. The Verge. https://www.theverge.com/2016/8/22/12585976/massachusetts-uber-lyft-tax-taxi-ride-hail

forces may steer AVs to be electric, EV market growth needs to be accompanied with a strategy to reduce emissions from the generation of electricity.[142] In particular, the advent of shared-use, autonomous, electric vehicles could bring environmental benefits, with some research estimating that they could slash per-mile emissions rates by up to 90% as compared to conventional vehicles.[143]

Irrespective of developments in AV and other advanced technology, policies focused on advancing EV deployment for personal use have been an important policy focus. EV regional adoption and travel can be fostered with policies such as the allowance of EVs to use high-occupancy vehicle lanes and the deployment of fast charging stations on regional corridors. Examples of EV corridors can be found in the states of Washington and Oregon. The State of Illinois also attempted to deploy stations along the route 66 corridor between St. Louis and Chicago, and the Kansas City Metropolitan Energy Center sponsored a study of EV regional corridors. Several regions have developed EV readiness plans or strategies, such as the North Jersey Transportation Planning Authority (NJTPA). Efforts have also been conducted at the state level to spur EV adoption. For example, a law passed by the state of Washington in 2009 requires local governments to develop regulations that allow electric vehicle charging as a use in certain zones. The purpose of the law was to encourage the market deployment of electric vehicles, and it designated a state agency to distribute ordinances, development regulations, and guidance to local governments to install electric vehicle charging infrastructure. The requirements were phased in over two years, starting with higher-population jurisdictions. The law established a collaborative process between the Puget Sound Regional Council (PSRC) and state agencies such as the Department of Commerce and the Department of Ecology. Model guidance was prepared through public process led by a Technical Advisory Committee that represented the key stakeholders in the electric vehicle space.[144]

Additionally, innovative green infrastructure technologies such as using solar powered roadways and sidewalks, and generation of energy through the kinetic energy of people or vehicles on roadways offer clean energy production directly through use of transportation. These technologies are still in early phases of testing and development. The implementation of these advanced technologies, as well as other more established technologies, are heavily influenced by public policy, including public funding and incentives. Table 10 lists some sample actions to support deployment of clean energy transportation technologies.

Table 10. Potential actions to ensure environmental quality.

Policy Area	Topic	Potential Policy	Responsible Agency
Infrastructure	Advancing EV adoption	Develop a vehicle electrification strategy for the region, including EV readiness plans. When determining charger placement, consider needs of freight and shared-use vehicles.	Illinois and Missouri DOTs and local governments
	Deploy Green Infrastructure	Evaluate the potential of deploying smart and sustainable infrastructure, such as solar highways, and a grid-integrated network of charging stations to effectively support EV adoption and use. Since autonomous electric vehicles will likely be served by wireless inductive charging, consider a	Illinois and Missouri DOTs and local governments

[142] Energy Information Administration. 2017. Study of the potential energy consumption impacts of connected and automated vehicles. https://www.eia.gov/analysis/studies/transportation/automated/pdf/automated_vehicles.pdf
[143] Greenblatt, Jeffrey, and Samveg Saxena. 2015. Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles. *Nature Climate Change* 5:860–863. doi:10.1038/nclimate2685
[144] See: Electric Vehicle Infrastructure: A Guide for Local Governments in Washington State (2010).

		strategy to integrate wireless charging into plans to deploy charging infrastructure.	
Operations	"Green" logistics	Implement policies to support and promote the use of low emission freight vehicles and strategies, such as green supply chain. Policies include incentives for efficient shipments, for platooning and/or fuel efficient vehicles, or for use of alternative fuels. Examples include allowing higher weight limits in freight vehicles using alternative fuels and/or automated logistics.	Illinois and Missouri DOTs and local governments

8. RECOMMENDATIONS: MOVING FORWARD FROM STRATEGY TO IMPLEMENTATION

Beyond recommended policy areas and regional strategies, East-West Gateway (EWG) is interested in actions to integrate emerging transportation technologies into its regional planning activities. In this regard, this section of the Strategic Plan includes recommendations of implementation actions for EWG to advance the broader technology strategy.

As a bi-state MPO, EWG works with many different governments on a variety of initiatives and at different levels of influence. EWG has the most discretion over its own operations, including committees, research, and modeling. Changes at this level allow staff and board members to become knowledgeable in dealing with technology issues and set the stage for working with outside partners. EWG also plays a central role in helping other agencies to implement transportation decisions that benefit the region through planning, programming, educating, and convening.

As such, this section of the plan addresses recommendations through the following roles that East West Gateway plays in the region:

1) Data, Modeling, and Analytics
2) Long-Range Planning
3) Programming and Funding
4) Pilot Program Development
5) Education, Convening, and Supporting Partner Efforts

These roles and recommended actions build on each other, and have several connections. Each of these roles is described below.

Data, Modeling, and Analytics

The following recommendations build upon East West Gateway's roles in generating and sharing research and information about transportation in the St. Louis Region, as well as analyzing and forecasting transportation conditions. These actions set the stage for future updates to the Regional Transportation Plan (RTP) and Transportation Improvement Program (TIP). Actions that relate to building internal capacity around data, modeling, and analytics are presented below.

Build staff skills in data analytics, such as by prioritizing technology experience and data analytics skills in hiring, and holding employee workshops and training for existing personnel.

As data management becomes increasingly important, and as the applications of data shift with technology, it is important to ensure that EWG staff have a full understanding of new sources of data and play a leading role in collaboration and coordination around data to support regional deployment efforts, as well as performance reporting.

Increasing staff skills around managing and analyzing data should start with assessing current staff knowledge and where staff sees opportunities for new forms of data to enhance system performance reporting. Based on the assessment of staff knowledge, next steps could include targeted trainings for existing staff or setting aside a training budget for staff to attend data related conferences. Additionally, EWG could prioritize data analytics skills and experience in future hiring decisions. EWG could also

consider developing a position focused on data and/or technology advancement. For instance, the Atlanta Regional Commission (ARC) has a staff person in their Mobility Services Division in the role of "Transportation Technology Principal Program Specialist." The responsibilities for this position include both planning and software development functions, including working on policy and planning to prepare the region for upcoming transportation technology needs and maintaining and developing web and mobile applications.

Develop a robust data collection plan, leveraging new forms of data available, to support use of performance measures such as reliability measures.

EWG, in coordination with regional partners, should assess whether to purchase and maintain local travel data from private companies (such as INRIX, HERE, and others) to serve as a substitute or supplement to government-collected data. Building on the region's ITS Architecture, which includes an operational concept for a regional ITS data sharing initiative that provides an ability for all agencies to share data on signal timing, weather data, and traffic flow information on arterials and freeways, EWG together with partners should examine potential for use of private-sector data collected through cell phones and/or GPS units to paint a more comprehensive picture of travel patterns. Many agencies like the Seattle Department of Transportation and City of Portland require a set of data to be shared as part of their engagement with transportation network companies (TNCs), like Uber and Lyft. Collecting and aggregating this data can help to provide a stronger regional understanding of current system performance conditions and travel patterns, which will help long-range and short-range investment planning. Other benefits include the ability to provide real-time traveler information to the public across modes, services, and jurisdictional boundaries and to enhance regional transportation system management and operations activities.

This private sector data could be used together with archived ITS data for Congestion Management Process (CMP) activities managed by EWG, including the development of data on more sophisticated performance measures such as reliability measures, and performance assessment of strategies being implemented. Given the relatively low congestion levels in the region, more robust data on travel time reliability, freight reliability, and system network usage would be helpful in prioritizing congestion and safety focused investments. In addition, EWG can work with partners to identify and coordinate collection of agency-specific data.

EWG also should examine its own data collection efforts to ensure these activities provide an up-to-date understanding of travel behavior. For instance, EWG should update the regional travel survey, which has not been updated in many years, in order to gain a more detailed and up-to-date understanding of travel behavior, including considerations such as TNC usage and patterns.

Enhance modeling to incorporate emerging transportation technologies into forecasts of travel patterns and impacts.

While the impacts of many emerging transportation technologies such as autonomous and connected vehicles are highly uncertain, these technologies are expected to have important impacts on travel demand and vehicle operating characteristics, such as the operating distances between vehicles, speeds, and crashes, which should be integrated into travel modeling.

The region's existing travel demand forecasting model for instance, could be run using alternative planning assumptions to reflect the potential implications of emerging technologies, such as:

- Decreasing the value of time in vehicles;
- Increasing freeway capacity (e.g., through reduced gaps between vehicles or narrower lanes);

- Behavioral factors, such as changes in auto ownership or increases in non-work trip making; and/or
- Changes in parking prices.

For instance, in a study in the Miami region, alternate scenarios of AV futures were examined using model adjustments to reflect capacity increases (80-100% for freeways and 10-30% for other facilities), reduction in the value of travel times (5-10%), decreased parking costs (20% reduction) and reduced out of vehicle travel times because of closer drop-offs (terminal times set to 1 minute).[145]

To conduct scenario analysis and forecast potential future system performance implications, EWG should examine the sensitivity of its regional model to changes in simple parameters such as those above to capture potential effects of autonomous vehicles (AVs) and TNCs. Alternative forecasts or sets of forecasts could be then accomplished via adjustments to the region's existing travel model. At present, the best estimations for the numerical adjustment for these variables and others are still highly conjectural, so experts suggest not making these adjustments for improved predictions as much as to take an exploratory approach to consider different possible futures.[146]

Examples of adjustments to roadway capacity under AV scenarios have ranged from 30% to 200% increases on freeways, for example, and up to an 80% increase on arterials.[147] Travel cost reduction assumptions adjustments ranged from 5% to 65%. In a modeling effort by the Puget Sound Regional Council (PSRC), cost estimates actually rose substantially under an AV scenario to $1.65 per mile (as compared to approximately 60 cents per mile for modern driving). This is because the PSRC scenario in question was assuming that all vehicle travel would be done through a system of for-hire vehicles that were centrally coordinated, perhaps as a government regulated utility, and that the vehicle cost rate included all external costs associated with the driving (emissions, congestion, fatalities, infrastructure maintenance, etc.).[148] However, under alternative assumptions, in which external costs are not included and ridesharing algorithms cut costs further, AV travel costs could be much lower, with some estimates of hypothetical AV operational costs as low as 18 cents per mile when including all of these effects.[149]

Given the uncertainty associated with the parameters of autonomous vehicles and other technologies, the exact values choice at this time are perhaps less important than the development of effective approaches to model the types of variations that will have important impacts and to consider uncertainty. For instance, the Atlanta Regional Commission used its model for the year 2040 to study the impacts of a fully automated future with 100% market penetration. This study considered four scenarios: '

- Increased capacity (doubled)
- Increased capacity (doubled) and reduction in value of travel time (50% decrease)
- Increased capacity (doubled), reduction in value of travel time (50% decrease), and reduction in vehicle operating costs (71% reduction in fuel efficiency)

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[145] Evans, 2016. Emerging Technology, Demographic Changes and Travel Behavior, presentation made at the Model Advancement Committee of the Florida Model Task Force, February 22, 2016. Documented in Florida Department of Transportation. 2016. Surveying Florida MPO Readiness to Incorporate Innovative Technologies into Long Range Transportation Plans. Available at: http://www.automatedfl.com/wp-content/uploads/2016/09/UF_BDV32_977_06_FINALREPORT.pdf

[146] Personal interview with Jeremy Raw, Federal Highway Administration Office of Planning, Washington, DC, June 13, 2017.

[147] Florida Department of Transportation. 2016. Surveying Florida MPO Readiness to Incorporate Innovative Technologies into Long Range Transportation Plans. Available at: http://www.automatedfl.com/wp-content/uploads/2016/09/UF_BDV32_977_06_FINALREPORT.pdf

[148]. PSRC. 2014. Using an activity-based model to explore possible impacts of automated vehicles http://psrc.github.io/attachments/2014/TRB-2015-Automated-Vehicles-Rev2.pdf

[149] Burns et al. 2013. Transforming Personal Mobility. The Earth Institute. Available at: http://sustainablemobility.ei.columbia.edu/files/2012/12/Transforming-Personal-Mobility-Jan-27-20132.pdf

- Increased capacity (doubled), reduction in value of travel time (50% decrease), and reduction in vehicle operating costs (71% reduction in fuel efficiency), and parking costs (reduced to 0).[150]

In the future, modeling improvements and new model platforms can be procured to better examine the impacts of new technologies. In particular, the advantage of activity-based modeling over traditional modeling that uses aggregate data is likely to grow as innovative services and technologies enter the market.[151] While it is not recommended that EWG transition to an activity-based modeling system in the near term given the potential costs of these models and relatively limited congestion in the region, activity-based modeling does hold advantages when trying to model new modes of transportation in a locally-tailored fashion. Activity based models allow for examination of the impacts associated with capacity increases of specific road pathways, as well as the adjustment of cost parameters associated with specific modes of travel.

Long Range Planning

The following recommendations build upon East West Gateway's roles in the long range planning process for the region and coordinating regional planning initiatives. The vision and goals set forth in the RTP are produced through collaboration with state and local governments and in consultation with the public. In addition to the RTP itself, EWG also plays an important role in regional plans and processes, including the regional ITS architecture, congestion management process (CMP), and development of various other plans, such as the Coordinated Human Services Transportation Plan.

EWG should work with local planning partners to realize the recommendations below:

Establish a Technology Advisory Committee at East West Gateway to advise on issues relating to technology in the region and to coordinate regional efforts.

The Technology Advisory Committee should play an active role in reviewing and informing technology-related recommendations in the RTP and TIP process, as well as to enhance on-going technical capacity building and sharing of information. Just as with many of EWG's existing committees, the Technology Advisory Committee should meet periodically, such as every other month, in order to maintain an on-going communication, support regional educational efforts around technology, and advance pilot project development. It should include members from local governments, local universities, Metro, and Illinois and Missouri DOTs.

Several regions have found that development of an advisory committee can be helpful in shaping considerations around technology as part of the long-range transportation planning process or are planning such groups. For instance, the Atlanta Regional Commission (ARC) in its 2016 Unified Planning Work Program (UPWP) identified establishing a Transportation Innovation Work Group as one of its actions to identify technological solutions in addressing transportation mobility, safety, and accessibility. The purpose of the work group was to include development of a Technology Vision for the region.[152]

As another example, the Capital District Transportation Committee, the MPO for the Albany region created an Environment and Technology Task Force in order to make recommendations for policies and actions for

[150] Florida Department of Transportation, 2016. Surveying Florida MPO Readiness to Incorporate Innovative Technologies into Long Range Transportation Plans. *Available at*: http://www.automatedfl.com/wp-content/uploads/2016/09/UF_BDV32_977_06_FINALREPORT.pdf

[151] ICF Expert Interviews

[152] Atlanta Regional Commission, 2015. 2016 Unified Planning Work Program for the Atlanta Region. Available at: http://documents.atlantaregional.com/tcc/2016/2016_UPWP-ARC_Adopted_12-2-2015.pdf.

the *New Visions 2040* Plan, considering topics such as alternative fuels, electric vehicles, new ITS technologies, signal technology, and other emerging technologies. The Task Force was composed of CDTC staff, plus representatives from the New York State Department of Transportation, the Capital District Regional Planning Commission (CDRPC), University at Albany (State University of New York), Rensselaer Polytechnic Institute (RPI), Climate Action Associates and Golub Corporation. The Task Force is not a policy decision making committee, but was asked to make recommendations to CDTC's Planning Committee and Policy Board. The Task Force developed a set of policy recommendations, including:

- The potential for future increased capacity resulting from totally automated vehicles should be strongly considered in highway and bridge design.
- Support smart growth with technology used to enhance communities.
- Proceed with short term and medium term investments, while maintaining flexibility to implement technology as it arrives.[153]

A similar Technology Advisory Committee at EWG could help to shape direction for policy and strategies for the update to the RTP.

Through the RTP outreach process, develop a shared vision for how technology could advance the region's values and recommend regional strategies, building on the discussion in this Strategic Plan.

To advance regional focus on technology deployment, EWG should build off of this Emerging Transportation Technologies Strategic Plan by developing a shared vision for how technology could support the region's values.

One mechanism for articulating this vision would be to develop a policy statement on the role of technology in the next update to its RTP. This action would emphasize regional consensus on the importance of advancing technology deployment to support the region's vision, and could form the basis for identifying or prioritizing strategies and projects that support this goal.

As an example of such a statement, the Transportation Planning Board (TPB) in the Washington, DC metro developed a set of eight Policy Goals to support its TPB vision. One of these stated goals as to "use the best available technology to maximize system effectiveness." The TPB has outlined several objectives supporting that goal, including:

- "a user-friendly, seamless system with on-demand, timely travel information to users, and a simplified method of payment",
- "improved management of weather emergencies and major incidents" and
- "full utilization of future advancement in transportation technology."

The TPB also identified strategies to achieve those objectives, such as "utilize public/private partnerships to provide travelers with comprehensive, timely, and accurate information on traffic and transit conditions and available alternatives" and "use advanced communications and real-time scheduling methods to improve time transfers between transit services."[154]

Given the strong foundation of the St. Louis Region's Ten Guiding Principles that create a vision for the region, it may not be as valuable to develop a policy statement on technology itself. However, within the

[153] Capital District Transportation Committee, 2015. CDTC New Visions: Enviornment and Technology Task Force White Paper. Available at: http://www.cdtcmpo.org/images/New_Visions_RTP/Environment-Technology-White-Paper-September-2015.pdf.
[154] Metropolitan Washington Council of Governments. 2017. https://www.mwcog.org/transportation/plans/tpb-vision/goals/

structure of the Guiding Principles, the RTP should more explicitly explore and identify strategies that utilize technology across each of the Guiding Principle areas. Section 7 of this Emerging Transportation Technologies Strategic Plan includes guidance on how to address potential effects of new technologies, including identification of key policies and strategies that could be advanced and integrated into the next update to the RTP. The public involvement plan and outreach used to develop the RTP should explore and validate regional priorities that include application of technologies, considering strategies such as the following (drawing on the discussion in Section 7):

Table 11. Potential Strategies for Consideration in RTP Update

Guiding Principle	Sample Potential Strategies
Preserve and Maintain the Existing System	• Advance use of technologies such as use of drones and use of connected vehicle data to efficiently monitor pavement and bridge conditions • Encourage use of advanced pavement technologies and design that increased infrastructure resiliency • Develop new preservation protocols to address changes in travel conditions associated with connected/autonomous vehicles
Support Public Transportation	• Encourage pilot initiatives to provide better first-mile last-mile connections to fixed route transit, such as autonomous shuttles, and partnerships with private sector service providers • Integrate fare payment systems to facilitate multi-modal travel options • Advance testing of automation in public transportation to reduce transit operating costs and improve service efficiency • Promote use of transit signal priority on major arterials
Support Neighborhoods & Communities	• Encourage private sector mobility services to serve disadvantaged communities • Support application of emerging transportation mobility services and technologies to strengthen accessibility for environmental justice populations
Foster a Vibrant Downtown & Central Core	• Develop mobility hubs where modes such as bicycle sharing, ridesharing, public transit, and private sector service providers intersect • Collaborative with developers, local governments, and businesses to support urban vitality by provide an optimal mix of space for on-street parking, shared use options, transit services, and green space, leveraging emerging transportation technologies
Provide More Transportation Choices	• Evaluate the use of "person delay" instead of vehicle delay when analyzing intersection performance and ITS to better understand wait times for people walking, bicycling, and taking transit • Evaluate standards used to determine crossing phases in order to ensure pedestrians of all ages and abilities are able to cross the street safely • Encourage the use of wireless detection sensors at traffic signals rather than inductive loops in order to help bicyclists trigger signals
Promote Safety and Security	• Invest in V2I communications infrastructure to support safety applications for drivers and pedestrians • Invest in cybersecurity of transportation networks as new technology for system management and automation in implemented
Support a Diverse Economy with a Reliable System	• Employ evolving applications of technology to support improved real-time traveler information and incident management • Support use of advanced data, communications, and automation to improve transit system reliability

	• Implement active system management strategies, including integrated corridor management to optimize reliability across the transportation network • Account for the impacts of connected and autonomous vehicles on effective roadway capacity in planning for long-term infrastructure investment needs
Support Quality Job Development	• Support application of emerging transportation mobility services and technologies to strengthen accessibility to jobs for low-income and minority communities • Work with the private sector, universities, and non-profit institutions to advance innovation in development and application of emerging transportation technologies
Strengthen Intermodal Connections	• Prioritize application of vehicle-to-infrastructure connected technologies to freight corridors
Protect Air Quality and Environmental Assets	• Support vehicle electrification efforts through electric vehicle readiness planning • Advance deployment of sustainable infrastructure, such as solar highways and use of kinetic energy for street lighting • Promote the use of low emissions freight strategies, including efforts to advance platooning of trucks and incentives for efficient shipments

Conduct scenario planning around transportation, land use, and technology to better understand potential alternative futures and to support more informed analyses of long-range investment priorities.

As part of its transportation planning process, EWG should conduct analysis to explore future scenarios addressing land use, transportation, and technology. The purpose of this analysis is to assess potential alternative futures, including widespread deployment of connected and autonomous vehicles, and their potential implications on congestion, reliability, and other outcomes, in order to support more informed investment and policy decision making. In particular, changes in travel demand and the effective capacity of the roadway and transit networks may yield quite different forecasts of future traffic congestion levels on the regional transportation network, and these differences should be accounted for in assessing the need for expanded infrastructure capacity.

Scenario planning is a valuable tool in instances of high uncertainty, and academics have recently argued for its application to transportation planning given the wide range of possible outcomes from several key emerging technologies.[155] Several regional planning agencies, such as the Baltimore Metropolitan Council (BMC) and the Atlanta Regional Commission (ARC), have also undertaken scenario planning that goes beyond traditional applications exploring land use and transportation alternatives to address alternative futures that address larger shifts and can help to identify the policy and strategy changes that can best capitalize on opportunities, mitigate or prepare for negative impacts, and address uncertainty.

As part of its *Maximize 2040 Plan*, the BMC utilized scenario planning to help steer investment decisions over a 25-year timeframe.[156] The MPO began scenario development with a survey to gather public input from key stakeholders about various forces that were likely to have large impacts on the region's transportation system. They grouped impactful forces into five categories—Social-Demographic,

[155] Lyons, G. and Davidson, C. 2016. Guidance for transport planning and policymaking in the face of an uncertain future. *Transportation Research Part A: Policy and Practice* 88(1):104-106. *Available at:* http://dx.doi.org/10.1016/j.tra.2016.03.012
[156] Baltimore Metro, 2014. Maximize 2040 Plan, Appendix C. *Available at:* http://baltometro.org/phocadownload/Publications/Transportation/Plans/Maximize2040/AppC_ScenarioThinking.pdf

Technological, Economic, Environmental, and Political—and then refined these forces in a focus group. Based on the findings from this focus group, they developed one scenario, called "Zuber Connected," in which significant advances in vehicle-to-vehicle and vehicle-to-network communication systems and sensors have occurred. Two workshops were held to discuss the impacts of each scenario on a variety of measures, and to determine what policies and investments would be effective responses to each.[157] As an example, planners gleaned from the scenario planning exercise that technological, environmental, and demographical factors would contribute to worsening infrastructure degradation, requiring increased efforts in asset management and the development of more tolerant materials.

The ARC conducted a visioning and scenario planning exercise, with implementation assistance from the Strategic Highway Research Program (SHRP2), which involved more quantitative analysis and forecasting. This scenario exercise included defining four alternative futures for the region in 2050, including one called "Technology Reigns" in which technological advances have vastly improved the quality of life for those who have the means to take advantage of the innovations, but the pace of change has overwhelmed the ability to fully address negative consequences. Other scenarios included "Full Steam Ahead" (largely business as usual), "Fierce Headwinds" (growth conditions have reversed), and "Ecotopia" (sustainability has risen to the forefront). The region used a combination of SHRP2 modeling tools, including the IMPACTS 2050 model, a scenario analysis tool to assess the potential impacts of socio-demographics on travel demand; the Regional Strategic Planning Model (RSPM), which supports "what if" analysis of changes in policies and trends, and allows sensitivity testing of strategies; and REMI, an economic impact analysis tool.[158] Several other regions, including the Chicago Metropolitan Agency for Planning, are considering or beginning to explore scenario planning that accounts for the uncertainties of future technologies.[159] This form of scenario planning is designed not as much to extrapolate the future but as an exploratory analysis to consider what might occur, tipping points, and policies and actions that may be needed to move toward positive scenario outcomes.

This process can be effective in considering risks due to technology changes, and can help in screening for technology obsolescence risk. Investment planning can be improved by examining a list of possible future scenarios and determining which investments would be most valuable under all futures. The Washington State DOT (WSDOT) took this approach in its *State Freight Mobility Plan*,[160] which included a planning analysis of four scenarios, one of which was a "technology savior" scenario characterized by new technology that improved abundance of goods and eases freight shipment. Trends that were likely to occur under *all* scenarios were identified, and were used to determine investment priorities.[161] Additionally, even if uncertainty precludes planners from making investment decisions at a given time, scenario planning can help determine at what threshold the decision could be made. For example, when trying to plan investments in CV infrastructure, industry movements and federal guidance will need to be closely watched, so that once it becomes clear which technologies become standard, those can be prioritized.

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[157] Baltimore Metro, 2014. Maximize 2040 Plan, Appendix C. *Available at:* http://baltometro.org/phocadownload/Publications/Transportation/Plans/Maximize2040/AppC_ScenarioThinking.pdf

[158] Atlanta Regional Commission. 2016. "Winning the Future: Sharpening Our Focus." Transportation Coordinating Committee. Available at: http://documents.atlantaregional.com/tcc/2016/2016-10-07/SHRP2_Visioning.pdf

[159] See, for example: Chicago Metropolitan Agency for Planning, Memorandum to the Economic Development Committee, June 27, 2016. *Available at:* http://www.cmap.illinois.gov/documents/10180/552715/6.0+Alternative+Futures+Scoping+Memo_ED+6.27.pdf/f8139c16-74a4-4e0f-93f6-ea801e589f4b

[160] WSDOT website. *Available at:* http://www.wsdot.wa.gov/freight/freightmobilityplan.htm

[161] FHWA Scenario Planning Guidebook, Chapter 3. *Available at:* https://www.fhwa.dot.gov/planning/scenario_and_visualization/scenario_planning/scenario_planning_guidebook/chapter03.cfm

This form of exploratory scenario planning can be conducted as part of the next update to the St. Louis region's metropolitan transportation plan. The exact scenarios of choice should be different from prior examples because scenarios should be tailored to the region, and because the understanding of emerging technologies is rapidly evolving. Typical steps in such a scenario analysis would include the following actions:

- Convene stakeholder meetings, including experts from universities, government, and the private sector to develop scenarios of the future;
- Conduct qualitative analysis, including assessments using stakeholders, to identify likely impacts of the differing scenarios;
- As feasible (based on modeling improvements discussed above), conduct quantitative analysis, such as modeling transportation outcomes; and
- Determine the drivers, policy levers, and strategies that perform well under the various scenarios.

Given the uncertain future, the results of such analysis can provide a more robust and useful discussion of investment and policy needs.

Include considerations related to emerging transportation technologies as a factor when prioritizing projects for the RTP.

Development of the investment plan in the RTP includes use of a structured prioritization process for evaluation of projects to include in the plan. Moving beyond policy statements and high-level strategies, EWG should consider including technology advancement as a factor when prioritizing and selecting projects for its next RTP.

The most recent RTP process included a project scoring system that provided up to 10 points for each of the 10 Guiding Principles, for a maximum score of 100 for each project in order to prioritize major investments, recognizing the fiscal constraint of the plan. This scoring system could be revised to specifically provide points for application of emerging transportation technologies. For instance, the scoring could be adjusted so that part of the score for each of the 10 Guiding Principles includes a component that addresses emerging transportation technology.

Alternatively, in addition to the 100 points that are allocated across the 10 categories, an additional category could be developed that assigns points (such as an additional 10 points) to projects that incorporate emerging/advanced technology components or that support future technology. The scoring can also consider risks to technology obsolescence so that it accounts for whether the technology is likely to continue to be valuable in the future.

Update the regional ITS architecture and deployment plan to reflect emerging transportation technologies and standards.

Beyond the development of the investment plan in the RTP itself, EWG should adapt the regional ITS architecture to integrate emerging transportation technologies in a standardized and interoperable manner. The existing St. Louis Regional ITS Architecture and Strategic Deployment Plan documents, completed in 2015, lay out a path forward in deploying ITS in the St. Louis Region, building on input from a wide array of transportation agencies in the region, as well as representatives of police, fire, and rescue staff, Lambert Airport, and the Federal Highway Administration.

Current documents identify ITS goals and include a proposed operational concept that moves from a system where agencies generally focus on managing their own assets and facilities, where traveler

information is agency-specific, and limited/ad hoc data exchange exists among agencies with limited to no interoperability of communications to one with extensive sharing of information. Under this operational concept, sharing of real-time multimodal traffic, transit, and incident information among agencies supports a "one-stop" regional traveler information system, which serves as a basis for Integrated Corridor Management strategies to improve system reliability and performance. It also creates a standard data archiving capability for regional performance management and monitoring as part of the Congestion Management Process (CMP).

The ITS Architecture describes centers (including the MoDOT Gateway Guide Traffic Management Center and the City of St. Louis Traffic Operations Center); connected infrastructure along the transportation network that performance surveillance, information provision, and plan execution control functions; and equipment used by travelers to access ITS services pre-trip and en-route. The Strategic Deployment Plan identifies specific projects, with estimated costs and time-frames, and identifies that the ITS infrastructure can be leveraged for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, often collectively referred to as V2X. Together, the ITS Architecture and Strategic Deployment Plan create a strong foundation for the next steps in the deployment of data exchange capabilities and transportation technologies in the region to support enhanced traveler information and system management capabilities.

Given the recent and emerging technology advancements, however, it is recommended that the Regional ITS Architecture and Strategic Deployment Plan be updated to reflect these advancements, and then periodically (for instance, every 3 years) to reflect emerging technology developments. The latest version of the national ITS architecture (Version 7.1) and the Connected Vehicle Reference Implementation Architecture (Version 2.2) are critical building blocks in ITS technology deployment with its use being promoted by U.S DOT and adopted by the Connected Vehicle (CV) Pilot sites, the Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Program awardees and the Smart City Challenge winner.

In particular, in an update, it will be important to consider how developments in ITS including connected and autonomous vehicle technologies will need to be reflected in the communications, data and physical architecture for systems in the region. Through regular updates, EWG can ensure that new technology does not get built in a silo and relies on available standards, and accounts for new technology trends, available data, and new services. This provides an opportunity to revisit some of the assumptions in the previous deployment plan which may have changed.

For instance, the Deployment Plan includes strategies such as to expand closed circuit television (CCTV) and enhanced freeway and arterial dynamic message signs (DMS). However, as noted earlier, radio advisories as well as ITS message signs and the way they are designed today will be obsolete in a fully connected environment, in which information currently is available through ITS message signs will be disseminated directly to the vehicles using V2I or V2X technologies and on-board units)."[162] This is not to say that investments in DMS or other technologies are not valuable, but that these investments need to be considered in relation to emerging technologies and potential evolving roles of the public and private sectors. Transportation agencies likely will still need to collect and share information on travel advisories, roadway conditions, and construction/work zone activity, but may transmit it through other sources, such as the internet cloud, so that it can be transmitted to vehicles and travelers through various applications. EWG and partner agencies must stay aware of market forces that may affect opportunities for new

[162] Carnegie Mellon University, "Connected and Autonomous Vehicles 2040 Vision." Prepared for Pennsylvania Department of Transportation, July 10, 2014.

deployments, or perhaps interfere with or supplant existing technologies, and regular updates would provide a mechanism for these considerations.

Potential implications of emerging technologies on the ITS Architecture and Strategic Deployment Plan for exploration in the near term would include:

- Preparing for a V2I future. If the NHTSA rule-making on DSRC comes to pass, the St. Louis region will need to get ready for a DSRC-enabled future. This includes figuring out a deployment strategy for enabling connectivity to the regional infrastructure starting with the traffic signals.
- Developing a clear role for the public sector in the delivery of traveler information that leverages V2X communications. Deployment strategies include creating a third-party data interface for public-sector owned data that is then shared with information service providers.
- Enabling collection of data from mobile fleets – With fixed infrastructure always constrained by limited budgets, the potential of data from probe and fleets is alluring. Early deployment strategies may include collection of mobile data from public fleets (maintenance vehicles, highway patrol) and developing the data hubs and portals necessary to support advanced decision support tools.
- Identifying potential corridors for advanced technology pilots is another element of the plan. Demonstration and operation of automated vehicles on dedicated rights of way and truck platooning pilots are examples of early deployment that should be considered as part of the update.

Update the regional Congestion Management Process (CMP) and ensure that other regional planning products (e.g., bicycle/pedestrian plans, coordinated human services plans, emergency response plans) integrate emerging transportation technologies.

Another closely related process and plan that needs to be updated in light of technology developments is the region's Congestion Management Process (CMP). Current congestion management practices used in St. Louis rely heavily on measures of recurring congestion associated with vehicle speeds (i.e., speed index, travel time index) and capacity (i.e., volume/capacity ratio and level of service), combined with multimodal measures (i.e., transit passenger trips, transit on-time performance) and measures of incident response and clearance time.

Nationally, the notion of trip reliability or travel time reliability is gaining in prominence as a vital component of mobility, with even greater importance than average travel times or speeds. Given the relatively low levels of congestion in the St. Louis Region compared to peer regions, there would be considerable value to focusing on developing a congestion management program geared around reliability. Such as shift requires revisiting monitoring and detection, as well as the management strategies, to focus on the sources of variability in the transportation system – adverse weather, traffic incidents, special events, work zones and bottlenecks. Archived ITS data, as well as private sector data collected through partnerships, can significantly enhance the detection and understanding of reliability on the transportation network, and will benefit from advancing ITS deployment in concert with the ITS deployment plan. Moreover, in forecasting future congestion using the regional model, the region should integrate consideration of the role of future technologies in reducing or exacerbating congestion, and build strategies to address those issues.

Included in the CMP process should be a discussion on the following:

- Future roles and responsibilities of transportation management centers, to shift from primarily managing their own facilities to greater sharing of data and communications across centers;
- Greater consideration of active traffic management elements including lane-control signage, responsive ramp metering, variable speed limits, intelligent signal control algorithms, and incident management. While some of these have been tried in the EWG region, there is an opportunity to advance the capabilities significantly in the area.

- Automated transit services, and improved service models, to improve reliability, reduce costs, and increase ridership.
- Potential role of strategies such as greater regional land use planning targeting development around high-capacity transit, urban centers, and use of shared modes.

Beyond the CMP, other regional transportation plans, including bicycle/pedestrian plans, coordinated human service plans, emergency response plans, and freight or other modal plans should integrate consideration of emerging transportation technologies. This could be accomplished by engaging the Technology Advisory Committee in the development of these plans. The Committee would support identification of potential technology strategies, as well as roles that future transportation technologies may have on needs.

EWG should also play an important role in collaboration to develop concepts of operations for enhanced system performance through corridor planning efforts initiated either by EWG or partner agencies, including Missouri DOT, Illinois DOT, and Metro.

Programming and Funding

The following recommendation is built upon East West Gateway's role in distributing federal funding and applying for federal funding for new projects. Successful integration of technology projects into the TIP prioritization and selection process will build upon the recommendations in the RTP.

Update the current TIP project selection process to encourage innovative technology projects and integration of advanced technology components.

EWG should work with partners to identify ways to update the current TIP project selection process for individual program areas to support advanced technology projects. The Technology Advisory Committee should be utilized in reviewing and informing recommendations for the TIP development process, and can engage with municipal staff on how to best augment the existing TIP project solicitation process. Initial steps would include discussing what sorts of technologies might be of most value in relation to individual program areas and what methods or scoring mechanisms would be most suitable to value the use of innovative technologies and methods.

Other MPOs and COGs have implemented adjustments to their TIP project criteria to support technology deployment. For example, the Cape Cod Joint Transportation Committee (CCJTC) and the North Jersey Transportation Planning Authority (NJPTA) both include the degree of advanced technological integration as a project scoring criterion. Specifically, CCJTC recommended a detailed scoring system for projects that assigns up to 100 points to each projects based on scores in the following categories: System Preservation and Modernization (35), Mobility (10), Safety (10), Economic Impact (10), Environmental and Health Benefits (10), Cost Effectiveness (15), and Policy Support (10). Within the System Preservation and Modernization scoring, 10 of the up to 35 points are assigned for "Use of modern technology to improve efficiency and support ITS regional efforts".[163]

The NJTPA, like EWG, uses different scoring criteria for individual categories of projects. For Highway and State Bridge Projects, for instance, it awards up to 24 points (our of a total of 1000) for addressing the

[163] CCJTC. 2016. Draft TIP Detailed Project Scoring Template. Available at: http://www.capecodcommission.org/resources/transportation/CCJTC_docs/8April2016meetingmaterials/DraftProjectEvaluationScoringTemplatewithProjectScores_4-5-16Draft.pdf

question, “Will it utilize technology to address traffic congestion effectively?”, where "technology" means things such as "traffic -actuated or computer-coordinated traffic signals, computerized incident management systems, or electronic toll collections systems."[164] The North Central Texas Council of Governments (NCTCOG) uses a similar approach in prioritizing projects for its Transportation Alternatives Set-Aside Program. Under this approach, projects are scored across multiple criteria, with one of the criteria being “Project Innovation”, which is described as follows: “Project implements innovative new treatments and technology that can serve as a model for the region” (5 out of a total 125 points). Examples provided include use of bicycle and pedestrian traffic count equipment, Rectangular Rapid Flash Beacons, and pedestrian hybrid beacons. [165]

EWG could adopt a similar approach and integrate a technology or innovation criterion into the scoring for its funding programs. A technology-oriented criterion could be integrated into various funding categories, including road and bridge infrastructure, transit, safety projects, freight and economic development, and traffic flow projects. Since the current criteria provide points in relation to each of the ten Guiding Principles, a recommended approach would be either to:

- Develop a separate criterion related to technology or innovation deployment, with points assigned; or
- Integrate technology into the rating factors across several of the Guiding Principles, such as safety and security, air quality/environment, and supporting a diverse economy with a reliable transportation system.

Under the second approach, for instance, for traffic flow projects, the criterion for rating in relation to safety would go beyond existing crash rates, fatality and serious injury rates, and inclusion of a safety countermeasure to potentially include points associated with use of technology-based safety applications. The approach should provide flexibility for unforeseen innovations that are deserving of credit, rather than specifically identifying individual technology applications.

Pilot Program Development

The following recommendations are built around East West Gateway’s unique role in the region both as a coordinating agency and as a funder of projects. In a region with limited funding resources, developing long-lasting partnerships and compelling project narratives is essential for attracting local, state, and federal funding.

Build federal grant readiness by creating a compelling grant narrative.

Building on the discussion of potential technology policy focus areas identified in Section 7, the St. Louis region is encouraged to identify transportation technology concepts to address specific local or regional transportation challenges. By identifying and developing consensus around a particular challenge (e.g., improving accessibility for a set of low-income neighborhoods to suburban jobs, or adopting solar panels and instrumented infrastructure to support sustainable energy generation and enhanced system

[164] NJTPA. 2007. Project Prioritization Criteria: Highway and State Bridge Projects. Available at: http://www.njtpa.org/getattachment/Project-Programs/Transportation-Improvement-Program/Scoring-Criteria/All_Criteria_01_08_07.pdf.aspx
[165] NCTCOG. 2017. Available at: http://www.nctcog.org/trans/sustdev/landuse/step/documents/2017_TASetAsideCFP_AppGuide.pdf

monitoring), these concepts will help to prepare the region to apply to federal grant applications, pilot projects, or new large-scale investment.

Identifying community challenges *preemptively* will help prepare for federal grant programs in a more timely and effective manner. For example, staff from the Mid-Ohio Regional Planning Commission, which won the Smart City Challenge, spoke about how their agency had been internally discussing those ideas before the US DOT released the Challenge information.[166] Based on the characteristics of previous grant winners, the St. Louis region is well suited to be competitive for federal grant programs. Its medium size, varied urban form throughout the region, and diverse transportation options all make the region primed for innovative solutions.

Successful funding requests, both from government and private sources, often require significant work in building relationships, finding opportunities, and coming to consensus on fundable solutions. For instance, the U.S. DOT Smart City Challenge finalists' proposals identified more than 150 industry and nonprofit partners pledging more than $500 million in resources, technology solutions, and technical support to implement smart city initiatives, and developing these commitments takes effort.[167] While this work requires resources be devoted to projects before it is clear whether future funding is available, it does present the opportunity to explore multiple sources of funding and lower cost options that could rely on local funding. This work ought to include:

- the identification of certain populations or geographical areas that are currently underserved or disadvantaged;
- the development of goals for improving system deficiencies; and
- building relationships with local leaders and community members through collaboration on small, locally funded projects to help build a narrative of local collaboration for future federal grant applications.

Many federal grant programs, such as the Smart Cities Challenge (SCC) and the Mobility on Demand Sandbox (MSB) have stated goals of improving access and equity to disadvantaged populations, and to support a multi-modal transportation system. Several of the efforts that are advancing, such as the Columbus SCC, Denver SCC, and the Tucson MSB, all had a strong focus on advancing the mobility options for disadvantaged populations within their regions, and addressing specific transportation and community challenges.[168]

Other grant program recipients have focused on augmented public transit systems to include first/last mile options. For example, the county of Pima, AZ included in its winning MSB program the establishment of a new subscription-based ride service, RubyRide, which operates similar to a standard transportation network company, but with a focus on higher utilization and occupancy and reduced cost.[169] Three other MSB grant winning programs have similar efforts to expand transit coverage through innovations in first/last mile transit.[170] The St. Louis region could seek similar advancements as part of a federal grant proposal, but would first need to conduct an assessment of current transportation gaps and system improvements to form

[166] ICF Expert Interviews

[167] US DOT. 2016. Smart City Challenge Lessons Learned. *Available at:* https://www.transportation.gov/sites/dot.gov/files/docs/Smart%20City%20Challenge%20Lessons%20Learned.pdf

[168] US DOT. 2016. Smart City Challenge Lessons Learned. *Available at:* https://www.transportation.gov/sites/dot.gov/files/docs/Smart%20City%20Challenge%20Lessons%20Learned.pdf

[169] Federal Transit Administration. 2016. Mobility on Demand Sandbox Summary: Regional Transportation Authority of Pima County. https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA%20MOD%20Project%20Description%20-%20Pima%20County.pdf

[170] Federal Transit Administration. 2016. Fiscal Year 2016 Mobility on Demand (MOD) Sandbox Program Projects. https://www.transit.dot.gov/research-innovation/fiscal-year-2016-mobility-demand-mod-sandbox-program-projects

a compelling narrative. This would require an assessment of current demographics and travel patterns, as well as perhaps community surveys or other means of gaging public needs.

Develop a grant tracking system/protocol to keep agencies informed of potential opportunities.

An array of national grant programs have been developed by federal agencies, primarily U.S. DOT/FHWA, that have been designed to advance technology adoption and catalyze innovative solutions that would otherwise have been slow to arrive. In addition to the larger and more publicized programs (Mobility Sandbox, ATCMTD, CV Pilots, and Smart City Challenge), other smaller programs have also been announced, such as the Exploratory Advanced Research (EAR) Program that sponsors research projects in focus areas such as CV technology, material science, human behavior, and technology for assessments, and technology for energy conservation.

Since many of the most exciting technology deployment opportunities might be unattainable without additional federal grant funding, federal grant programs have played an important role in spurring innovative programs. Many of the most technologically savvy and advanced technology programs happening today at the regional and MPO level are resultant of these programs. Given the range of grant programs, which are a mixture of singular and recurring monies, it is advisable to establish a protocol within EWG for tracking information on grant programs pertaining to new technologies, and for sharing that information with regional partners.

Develop and fund a regional technology deployment pilot program to spur deployment of advanced technologies.

Beyond preparing for Federal or other grant opportunities, EWG can directly develop and fund a technology deployment pilot program to help spur innovative projects. This pilot effort would come out of the RTP effort and need to have dedicated funding in the TIP.

In the process of identifying regional gaps and weaknesses (as part of developing a federal grant narrative), EWG and regional partners may also identify local problems that could be solved by technology pilots without federal grant money (this task could potentially be undertaken by the Technology Advisory Committee). A program could be organized with a focus on addressing a particular regional challenge or priority theme, such as deployment of vehicle-to-infrastructure safety applications. Other key themes might include, security, transit access, infrastructure condition, equity, or environmental quality. Alternatively, the initiative may be particularly beneficial if it combines several themes and allows agencies to propose projects for funding that help to support multiple goal areas.

A program directly funded by EWG should ideally leverage other public agency or private sector funding or demonstrate cost savings rather than having on-going maintenance costs. Previously mentioned examples of the PSTA and Summit, NJ partnerships with TNCs that reduce costs from paratransit service provision and parking, respectively, offer examples of innovative ideas that were not dependent on federal innovation grants or other federal funds. EWG could determine areas where service provision or maintenance is especially expensive, and then search for targeted solutions that would reduce or maintain costs while also advancing the *Guiding Principles*. Project concepts could be offered not only by local governments but also by universities or university partnerships, which could reduce costs relative to partnering with private organizations, and offer a means of program evaluation. Although there are many constraints on Federal funding that would be used by EWG for a pilot program, many Federal programs allow funding for innovative

efforts. For instance, the Congestion Mitigation and Air Quality Improvement (CMAQ) Program guidance notes eligibility for public-private-partnerships and "innovative projects."

In addition to a funded program directly focused on transportation technology, EWG also could expand its "Great Streets" program to spur local planning and policies that support urban centers and effective land use planning that accounts for technology. Some MPOs, like the Metropolitan Washington Council of Governments (MWCOG) and ARC have technical assistance programs to help local governments implement innovative livability projects by providing small grants to local governments. Given the important potential implications of transportation technologies on urban form, public street space, and potential to encourage sprawl, this program effort could be expanded to help support local efforts to spur effective first-mile last-mile connections to transit, planning for mobility hubs, or smart parking.

Education, Convening, and Supporting Partner Agency Efforts

The following recommendations build upon East West Gateway's unique role in the region providing education and a convening place for local governments in a bi-state region. Approximately 90% of respondents to the regional stakeholder survey on emerging transportation technology indicated they would view agency efforts to pursue partnerships for technology deployment either "positively" or "very positively."

The following recommendations will help East West Gateway support local governments, Metro, community members, and state governments in making informed decisions about technology, to be better prepared for emerging technology, and foster partnerships.

Work with local universities to identify opportunities to collaborate on advanced technology pilot programs

Research is a key action to promote the development and implementation of new technologies, and many of the regions that have been piloting emerging transportation technologies have built on strong involvement of academic institutions. For instance, Carnegie Mellon University (CMU) has played a lead role in advancing research that has led to deployments and testing of autonomous vehicles in Pittsburgh. These efforts have included development of the joint General Motors-CMU Connected and Autonomous Driving Collaborative Research Laboratory to speed up research efforts on the next generation of vehicle information technology. While CMU is somewhat unique based on its strong robotics program, the St. Louis region has the benefit of strong institutions of higher education, including Saint Louis University, Washington University, and the University of Missouri – St. Louis, among others.

Given limited staff and resources in public agencies, public agencies benefit from partnering with research and corporate institutions, such as universities and think tanks, to complement their efforts. Also, the inclusion of research institutes can help to monitor and analyze program effectiveness and impacts, which are essential to scaling and replicating new programs. For these reasons, including research organizations as partners in new technology programs has been encouraged in the guidance for federal grant programs, and the importance of these partners is underscored by their inclusion in so many of the winning federal grant programs. For example, the joint submission to the Federal Transit Administration (FTA) Mobility on Demand (MOD) Sandbox Program by Puget Sound and Los Angeles County partnered with both the Eno Center for Transportation, a non-profit think tank organization, as well as the University of Washington Transportation Center, a university research center. Similarly in all three of the federal CV Pilot Programs, academic research institutions were brought in as partners to help analyze program performance evaluation.

In the process of identifying and planning potential projects, be they part of federal grant applications or otherwise, EWG should work to convene regional partners and members of nearby academic institutions to identify instances where those institutions could provide valuable input and help analyze certain aspects of the program that may be difficult for a municipal agency. This could be accomplished by the Technology Advisory Committee, which could first identify which organizations might be suitable fits, and then engage in discussions about their capabilities and interest.

Coordinate peer-to-peer workshops to share best practices and lessons learned, and to help support innovative practices among local, regional, and state agencies

EWG should utilize the Technology Advisory Committee to convene workshops on lessons learned to help scale innovative practices from one locality throughout the region, and to avoid pitfalls. Valuable lessons worth discussing could relate to topics such as:

- Opportunities for enhancing public-private partnerships, such as for first-mile last-mile connections to transit;
- Opportunities for enhancing regional data sharing;
- Changes in procurement policies to advance innovation;
- Workforce issues, including hiring data-savvy staff, such as a Chief Data Officer and a Chief Data Analyst, possibly by pooling resources from multiple agencies
- Lessons from experiences implementing technology
- Knowledge on the value and capabilities of other academic and corporate project partners

As an example, the Metropolitan Transportation Commission (MTC), the MPO for the San Francisco Bay Area, has a Technology Transfer Program, which offers free, half-day seminars on a variety of topics of interest to local traffic engineers, planners, and students. Some specific recommended issues are discussed further below.

Facilitate regional discussions to identify opportunities to enhance services through private sector partnerships.

As the primary driver of transportation technology innovation, the private sector can play an important role as a partner to public sector agencies in deploying new technologies to enhance services and meeting customer needs. Many state and local governments, as well as transit agencies, across the nation have initiated partnerships with private companies, labeled as public-private partnerships, to support improved traveler information, service connections, and deployment of technology applications. At a regional level, EWG should facilitate discussions among agencies, such as Missouri or Illinois DOTs, Bi-State Development (BSD) / Metro, the City of St. Louis, counties, and other local governments to identify specific regional problems that would be ripe for a public-private partnership, with a focus on goals such as expanding access to transit, improving traveler information, or reducing operational costs.

Specific opportunities might include:

- *Partnerships between BSD/Metro and mobility companies to support first-mile last-mile connections to transit, or to reduce operating costs for Metro Call-A-Ride paratransit and other services*. Numerous MPOs have recently sought these sorts of partnerships due to their potential to cut costs, improve accessibility and service, and to help facilitate a more comprehensive transportation system that could potentially reduce the need for car ownership. It should be noted that partnerships for first-last mile connections are not limited to dense, urban spaces; a recently announced partnership between Lyft and Dayton Regional Transit Authority (RTA) in Ohio consists of allowing rural residents to book Lyft rides to and from bus stops at discounted fares, thus granting

rural county residents access to the RTA system.[171] The Dayton program also will provide ADA accessible vehicles and call-in options to customers requiring those provisions.

These sorts of partnerships would be valuable to the EWG not just because they could improve transit coverage and service quality, but also because by reducing costs of serving certain routes, such as those with sparse ridership, they could also allow transit funds to be reallocated to improve service elsewhere. While forming partnerships to expand public transit may be in the interest of some TNCs or other mobility companies, EWG should assist regional partners in leveraging their assets in the negotiation of these partnerships, since private companies may not necessarily be inclined to form partnerships. Agencies control assets such as parking spaces, street right-of-way, and even permission to provide service – all of which can be used in negotiations.[172] EWG should play a role in ensuring that local agencies are aware of the value that their assets have, and of the options for leveraging them (e.g. HOV lane and parking access, reducing parking prices, agency advertisements or endorsements,[173] right-of-way, regulatory requirements, or subsidies).

- *Data sharing partnerships or purchase agreements to provide expanded real-time traveler information and improve planning.* A number of states and cities have developed agreements with companies like Waze, INRIX, and HERE to provide improved multi-modal traveler information, with the public sector providing relevant information on construction and anticipated work zones. Early adopters to these types of data sharing partnerships included localities such as Boston, MA and Los Angeles County, CA, as well as State DOTs in Utah and Florida. As an example, the Florida Department of Transportation (FDOT) has an agreement with Waze, signed in March 2014, which allows Waze to tap into FDOT's 511 system. In addition, FDOT supplies Waze with information on construction, special events, speeds limits, evacuation routes, and other information. Waze agreed to let FDOT have access to the data it collects to enhance FDOT's information dissemination. While there are many details to the agreement, one of the requirements is that each party must recognize the other as the source of information.[174] Data sharing agreements have also been formed with TNCs either via regulation or by leveraging public sector assets, though TNC data is not necessarily as comprehensive as data from companies like INRIX, StreetLight Data, or Teralytics.

Facilitate discussions to explore changes in procurement policies to advance public-private partnerships and innovation.

The process of engaging with technology companies – be they ridesourcing services, trip aggregators, data providers, or others – is somewhat complicated by the existing public agency procurement process, which can preclude targeting specific market players. The traditional constraints of specifying requirements and putting out a bid for services, which often prioritize award to the lowest cost bidder, does not typically foster innovation or engage the private sector in developing new solutions to problems. In several cases of existing partnerships with new technology companies (e.g. the KCATA partnership with Bridj), procurement policies had to be waived or altered.[175] Alternately, some agencies have found workarounds by negotiating partnerships through an existing contract. For example, transit agencies in Memphis (mata) and Raleigh-Durham (GoTriangle) have taken this approach by entering into contracts with their existing trip-planning provider, TransLoc, who in turn developed an agreement with Uber to include its trip data in the transit trip planning application.[176]

[171] Wiedle, Jeremy. 2017. New RTA partnership to establish service for rural customers. Dayton.com. Available at: http://www.dayton.com/news/local/new-rta-partnership-establish-service-for-rural-customers/5JBYgbaVfg0AfUVKK5ryfJ/amp.html
[172] TransitCenter. 2016. Private Mobility, Public Interest: How public agencies can work with emerging mobility providers.
[173] For example, see: MBTA, 2016. http://www.mbta.com/about_the_mbta/news_events/?id=6442456462
[174] For more information, see: FDOT, 2014. http://www.fdot.gov/traffic/Newsletters/2014/2014-Aug.pdf
[175] TransitCenter. 2016. Private Mobility, Public Interest: How public agencies can work with emerging mobility providers.
[176] TransitCenter. 2016. Private Mobility, Public Interest: How public agencies can work with emerging mobility providers.

To optimize agency flexibility in this space, EWG should convene public agencies to identify challenges related to their procurement policies and to identify best practices in innovative contracting. These agencies responsible for providing transportation services include BSD/Metro, Missouri and Illinois DOTs, the City of St. Louis, and other local governments. This effort could result in changes in organizational processes associated with procurement. For instance, Los Angeles Metro created an Office of Extraordinary Innovation, which is designed to identify, evaluate, develop, and implement new approaches that have potential to improve mobility for people in the region. To carry out this work, the office set up a process to receive unsolicited proposals, which allow private-sector companies working on transportation innovations to present new ideas directly to Metro for review and evaluation, jump-starting the traditional public procurement process.

Build regional capacity around data collection and analytics

As noted earlier, tremendous advances in big data are creating new opportunities for monitoring system performance, applying dynamic systems to improve the efficiency of multimodal transportation operations, to understand customer needs and travel demands, and to support effective asset management. In this sense, data is an important asset that is becoming more readily accessible as the Internet of Things increase its coverage and connectivity equipment becomes standard. Data sharing was noted in every expert interview in which the topic arose, where interviewees stressed the value of building capacity in public agencies to understand technology and data.[177]

As suggested in the stakeholder survey, the complex nature of overlapping governments in the St. Louis region could pose unique challenges to data sharing efforts. Although the region's ITS architecture lays a framework for collaboration around data sharing, agencies will increasingly benefit from having staff that bring advanced capabilities in data analytics. Some agencies, such as Colorado DOT, are setting up a Chief Data Officer group within the State DOT that reports to the CIO. This institutional approach could be advanced not only at the State DOT level but within local governments to advance use of data in applications.

Conduct surveys or assessments of local governments on a recurring basis as to their level of technology awareness and readiness in order to create useful educational tools and conferences

Building on the regional survey conducted to develop this Emerging Transportation Technologies Strategic Plan, EWG should develop and conduct surveys or assessments of regional government on technological readiness on a recurring basis. As the private sector continues to rapidly evolve, the nature of technology and its associated impacts will change and continue to pose challenges for government. Existing technologies may be shown to have unexpected effects, or previously unforeseen applications, and currently unproven technologies like aerial drones and hyperloop systems might eventually come to the forefront of policy decision-making. Therefore, the process of facilitating information exchange and education on the current state of technology will be an iterative process. To best disseminate new information in a way that fills gaps in agency understanding and addresses the most pressing needs of regional partners, EWG should convene key leaders or conduct surveys to gage the level of understanding and needs of regional partners, in order to create useful educational tools or conferences.

[177] ICF Interviews with Industry Experts.

APPENDIX A: EXPERT INTERVIEWS CONDUCTED

As part of the development of this strategic plan, the research team held discussions with 15 "thought leaders" from the private sector, academia, and the public sector to gather insights on transportation technology, implications, and policy considerations (listed in alphabetical order). Their contributions to assessing the state of the practice, trends, and implications, provided valuable input to the development of this document.

Interview Participants
1. Gary Carlin, INRIX
2. Adam Cohen, Transportation Sustainability Research Center, UC Berkeley
3. Barry Einsig, Cisco
4. Matt Gordon, Anheuser-Busch
5. Anita Kim, U.S. DOT Volpe Center
6. Kara Kockelman, University of Texas, Austin
7. Brad Miller and Chris Cochran, Pinellas County Transit Authority
8. David Pickeral, Consultant, formerly IBM Smarter Cities
9. Carol Schweiger, Schweiger Consulting and New England ITS
10. Robert Sheehan, U.S. DOT Intelligent Transportation Systems Joint Program Office
11. Steven Shladover, PATH, UC Berkeley
12. David Somo, ON Semiconductors
13. Thea Walsh, Mid-Ohio Regional Planning Commission
14. David Woessner, Local Motors
15. Stephen Zoepf, Center for Automotive Research (CARS), Stanford

APPENDIX B: ANTICIPATED IMPACTS OF EMERGING TECHNOLOGIES ON THE REGION'S GUIDING PRINCIPLES

Impacts associated with each of the *Guiding Principles* are described below.

Preserve and Maintain the Existing System

Ensure the transportation system remains in a state of good repair.

Emerging technologies will likely have opposing effects on the ability of transportation agencies to maintain the transportation system in a state of good repair. On the one hand, advanced infrastructure offers potential for reduced maintenance. The highways of the future could be paved in solar LCD panels that can repair themselves, melt snow, and provide lighted lane striping, all while generating a clean source of energy. Preventative maintenance on the region's bridges and highways could be made more efficient and targeted through the use of drones for inspections, and direct instrumentation of highways in regard to conditions such as potholes and cracking. The ability of vehicles to travel closer to each other safety is also expected to increase the effective capacity of highways, which may mean less needs for costly expansion of capacity.

On the other hand, improvements in vehicle fuel efficiency, adoption of EVs, and potential for reduced vehicle ownership are expected to reduce traditional sources of transportation funding from fuel taxes, as well as potentially vehicle registration fees. These impacts on transportation funding highlight the importance of policies to shift transportation funding to new sources, such as road pricing systems that charge based on mileage or congestion levels.

Support Public Transportation

Invest in public transportation to spur economic development, protect the environment and improve quality of life.

Impacts of technology advances on public transit are highly uncertain, and may be very dependent upon regional investment choices and policies. On the one hand, public transportation could greatly benefit from advanced technologies to improve the rider experience and service efficiency. Real-time arrival information and the presence of Wi-Fi both have potential to increase ridership and improve the user experience, though previous studies indicate these effects are modest.[178,179] Enhanced transit signal priority and other system operations enhancements, including use of autonomous vehicles, could also improve transit travel time competitiveness. On-demand services could help to provide first-mile last-mile connections to fixed route public transportation, and integration of these services into more of a mobility on demand model could help to support public transit. This type of connectivity of services would allow mass public transportation systems like the St. Louis MetroLink rail to be synchronized with other systems such as on-demand services.

[178] Tang, Lei, and Piyushimita Thakuriah. Ridership effects of real-time bus information system: A case study in the City of Chicago. *Transportation Research Part C: Emerging Technologies* 22(1):146-161. http://dx.doi.org/10.1016/j.trc.2012.01.001

[179] Dong, Zhi, Patricia L. Mokhtarian, Giovanni Circella, and James R. Allison. The estimation of changes in rail ridership through an onboard survey: did free Wi-Fi make a difference to Amtrak's Capitol Corridor service? *Transportation* 42(1):123-142.

It is debated to what extent current mobility services are complementing or substituting public transportation. A widely cited report by the American Public Transit Association (APTA) and the Shared-Use Mobility Center (SUMC) surveyed users of these services and found that they generally had lower rates of car ownership, used transit more often, and walked and biked more.[180] This corroborates some of the earliest studies on TNC usage that illustrated that they were replacing primarily taxi trips in San Francisco.[181] However, more recent reports suggest that, as the user base of these services expands past the early adopters and as their prices continue to fall, they are beginning to compete more with transit systems.[182] In the long-term, these services may benefit from automation reducing operating costs, specialized vehicle design for shared-use functionality (such as small size and electric engines), and improved routing algorithms. Small, electric, and automated vehicles have been estimated to be able to provide ride services at as cheaply as 0.18 $/mile, much cheaper than typical transit fares.[183] Even if not automated, vehicles may start to be designed explicitly for shared-use functionality, and routing algorithms may improve to lower costs. With these sorts of developments, it is likely that private services would heavily compete with transit ridership, unless explicit policy measures were taken.

It should be noted that private mobility companies such as today's TNCs may themselves be a form of public transportation in the future. As more cities consider targeted subsidies of certain Uber and Lyft rides, this reality is already underway. Also noteworthy is that traditional transit services like light rail and high capacity buses could be among the first services to benefit from automation through the development of small low-speed vehicles designed explicitly for first/last mile transportation, such as the EZ10 shuttle concept.[184]

Support Neighborhoods and Communities throughout the Region

Connect communities to opportunities and resources across the region.

The impacts of transportation technology on supporting neighborhoods and communities appears somewhat limited, and is dependent in part on policy choices. Technology as a whole has vast potential to enhance access of people to opportunities, including employment, health care, and education, as well as access to products through e-commerce, particularly disabled and elderly populations for whom mobility using motor vehicles may be a challenge. Many of these effects are not so much the result of transportation technology as they are of general mobile connectivity. New shared mobility services, however, could help to connect people without access to a private vehicle to a wider array of opportunities, as long as these services are affordable. At the same time, e-commerce may adversely affect brick-and-mortar stores and could have some detrimental effects on communities, and lower-income people might be left without access to some of the benefits of new services.

Public policies to help ensure that the benefits of enhanced accessibility and safety from technology is accessible to lower-income communities and those struggling with higher rates of unemployment, crime,

[180] APTA. 2016. Shared Mobility and the Transformation of Public Transit. Research Analysis. https://www.apta.com/resources/reportsandpublications/Documents/APTA-Shared-Mobility.pdf
[181] Rayle, L., Susan Shaheen, Nelson Chan, Danielle Dai, and Robert Cervero. 2014. App-Based, On-Demand Ride Services:Comparing Taxi and Ridesourcing Trips and User Characteristics in San Francisco. UC Berkeley Transportation Center. UCTC-FR-2014-08.
[182] Schaller Consulting. 2017. UNSUSTAINABLE? The Growth of App-Based Ride Services and Traffic, Travel and the Future of New York City. *Available at:* http://www.schallerconsult.com/rideservices/unsustainable.pdf
[183] Burns et al. 2013. Transforming Personal Mobility. The Earth Institute. *Available at:* http://sustainablemobility.ei.columbia.edu/files/2012/12/Transforming-Personal-Mobility-Jan-27-20132.pdf
[184] See the Easy Mile website for more detail on the EZ10 shuttle: http://easymile.com/

and social problems, and connects people to vital services would play a key role in ensuring support for this principle.

Foster a Vibrant Downtown

Improve access to and mobility within the central ore by all modes to increase the attractiveness of St. Louis and strengthen the regional economy.

The largest impacts to downtown vibrancy are likely to be in the long-term (10-25 years). Several large-scale changes in consumer behavior related to technology could pose changes to downtown areas like those in St. Louis. The shift from physical access to electronic access for many things, such as shopping, medicine, school, and entertainment, could reduce the incentives for a vibrant centralized downtown. Access to AVs could reduce the time burden of traveling long distances, since vehicle occupants could be reading, working, or undertaking other activities, which might also encourage further suburban sprawl.

However, several other emerging technologies have potentially beneficial impacts. For example, a study by the International Transport Forum (ITF) modeled the impacts of substituting private car travel for a fleet of ridesharing mini-buses (autonomous or driven) in Libson, Portugal, and found that such a fleet could "completely remove the need for on-street parking" and up to 80% of off-street parking.[185] Reduced parking could free up space for additional retail buildings, services, or public spaces – all of which could help foster a vibrant downtown area. It should be noted that the benefits described in the ITF study are far from inevitable – they depend on a high penetration rate of shared vehicles, and on using a ridesharing trip algorithm for all trips. However, even a fraction of these benefits would be helpful for fostering vibrant downtown spaces; currently, 31% the average central business district in U.S. cities is consumed by parking, but that space can be repurposed to lower housing costs or provide walkable, public spaces.[186]

Provide More Transportation Choices

Create viable alternatives to automobile travel by providing bicycle and pedestrian facilities.

Technological impacts for this metric are very likely to be positive, especially if the phrase "automobile use" in the EWGCOG description is taken to mean "*personal* automobile use." Private mobility companies, riding the wake of the IT and communications revolutions of the past decade, are providing a litany of new services in the range of bikesharing, carsharing (person-to-person as well as with company-owned vehicles), ridesourcing (e.g. Lyft), and microtransit (e.g. Bridj). Even options such as bikesharing and carsharing, which have existed for decades, are continually becoming more accessible and appealing through the advent of mobile phone technology that can assist in trip planning and finding available bikes or cars for use.

Promote Safety and Security

Provide a safe and secure transportation system for all users.

[185] ITF. 2016. Urban Mobility System Upgrade: How shared self-driving cars could change city traffic. ITF, OECD, Corporate Partnership Board. http://www.itf-oecd.org/sites/default/files/docs/15cpb_self-drivingcars.pdf
[186] RCLCO. 2017. Autonomous Vehicles: A Real Estate Road Map to the Future. *Presented at*: New Partners for Smart Growth Conference, Feb. 4, 2017.

Safety and security are the most direct and clearly positive impacts expected from emerging transportation technologies. Many emerging technologies, such as V2I and V2V connections, autonomous braking systems (as well as more advanced AV technology), and smart infrastructure all have improved safety at the core of their design. Vehicle automation, in particular has been widely lauded as having potential for drastic safety improvements, as 94% of accidents are currently attributed to human error.[187] Automated braking systems are likely to be mandated on new vehicles in the near future, and are already present in some vehicles. As the different levels of automation proliferates, it will likely yield safety benefits even if its capabilities are restricted to very specific purposes/settings.

Moreover, in the near term, safety improvements could also come from shared mobility services for two reasons. First, early evidence suggests that intoxicated persons are using TNCs such as Uber and Lyft rather than their own vehicles, suggesting that drunk driving rates could fall with the advent of TNCs.[188] Second, services like TNCs offer an easy way to hail a ride at any time and any location, allowing users to escape any unsafe situations. Subsequently, cities such as LA[189] have partnered with TNC service providers for "guaranteed ride home" programs, which allow subsidized rides in these services in instances of emergency. Lastly, given the emerging evidence that smartphone use may be tied to increases in auto accidents,[190] modes that allow users to enjoy car travel without needing to focus on the road (such as TNC rides or AVs) could be a valuable tool for limiting distraction-caused incidents.

Support a Diverse Economy with a Reliable System

Reduce congestion and improve travel time reliably to support the diverse economic sectors of the region.

Overall impacts on the economy from transportation technologies are uncertain, but it is encouraging to see that there are emerging technologies designed to improve inter-urban passenger movement, freight, and regional travel. Overall, the direct impact of vehicle technology improvements will enable vehicles to travel more closely together, enabling more vehicle throughput within the existing transportation system that should help to reduce traffic congestion. Improvements in monitoring roadway conditions, as well as safety improvements, should directly result in fewer vehicle incidents, which would improve reliability of the system since crash-related incidents are a significant source of nonrecurring delay. In addition, better traveler information in vehicles enables travelers to re-route to minimize time stuck in congestion, and helps transportation agencies to better monitor conditions to remove debris or incidents that may be impeding traffic. AV technology has the potential to free up an estimated 2.7 billion unproductive hours spent commuting for work or leisure every year, which have been valued at $447.1 billion annually in the U.S.[191]

At the same time, increased vehicle travel associated with AVs and more mobility options, as well as direct package deliveries, could offset some of these benefits.

[187] NHTSA. 2015. Traffic Safety Facts. DOT HS 812 115. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115
[188] Texas A&M Transportation Institute. 2016. TTI Researchers Investigate Reasons Impaired Drivers Choose Transportation Network Companies to Provide Safe Rides. https://tti.tamu.edu/group/cts/2016/10/05/tti-researchers-investigate-reasons-impaired-drivers-choose-transportation-network-companies-to-provide-safe-rides/
[189] LA County Metropolitan Transportation Authority. https://www.metro.net/riding/rideshare/grh/
[190] Morgan, David. 2015. Smartphones may have role in rise of U.S. traffic deaths. Reuters. http://www.reuters.com/article/us-usa-autos-deaths-idUSKBN0TD2KP20151125
[191] Kockelman, Kara, and Lewis M. Clements. 2015. Economic Effects of Autonomous Vehicles. http://www.caee.utexas.edu/prof/kockelman/public_html/TRB17EconomicEffectsofAVs.pdf

Support Quality Job Development

Support the growth of wealth producing jobs that allow residents to save and return money to the economy.

Transportation technology has potentially very positive and also very negative impacts for supporting quality job development. In the long-term (10-20 years), vehicle automation could reduce direct employment in the transportation sector, as jobs related to driving (everything from truck drivers to taxi and transit service drivers) could be displaced. A survey of self-identified AV experts in 2014 found a median estimate of 2025 for when vehicles would be able to safely drive themselves in both highway and urban settings, and 2030 for when there would be no need for a backup driver in those settings.[192] While these are generally jobs with limited skill requirements, they provide a good income for many people, and loss of these jobs, like the loss of manufacturing jobs in the region over the past decades could adversely affect many households.

However, automation, mobility services, and connectivity have the potential to reduce barriers to travel and facilitate market interaction and overall economic growth. Moreover, new technology creates opportunities for quality job development in emerging fields, including advanced logistics and data analytics, as well as in the development of innovative technologies and services that will be in demand in relation to these new vehicle and infrastructure technologies.

Strengthen Intermodal Connections

Connections Support freight movement and connections that are critical to the efficient flow of both people and goods.

Technology is highly likely to provide improvement in freight movement and passenger intermodal connections. To start, advances in real-time arrival information, mapping, and trip planning, either through government or industry applications, can improve user experience in multi-modal trips. Future advancements in analytics and traffic management, paired with vehicle and infrastructure connectivity, could facilitate linkages between modes. Applications that plan both a metro rail trip and a trip in a shared vehicle, for example, could transfer information allowing the vehicle to be ready at the transit stop right as the traveler gets off the train. The development of mobility-as-a-service (MaaS) applications in particular – which allow users to buy mobility monthly mobility packages covering several modes, and do all planning and payment for trips through a single app – have potential to ease the process of transferring between modes, or taking different modes in each direction of a round trip.

From a freight perspective, advances in connectivity and transfer of information will integrate and optimize the supply chain. The overall cost of logistics operations are expected to decrease through these technologies, as processes and data sharing are performed in a faster and more reliable manner. For example, the Kansas City Cross-town Improvement Project (C-TIP) integrated real-time information, dynamic route guidance, a wireless communication platforms for drivers and dispatchers, and other new technologies. At the conclusion of the pilot program, there were measurable "truck travel time savings and emissions reductions in operational tests."[193] The features in C-TIP are the foundation for Freight Advanced

[192] Underwood et al 2014. Automated Vehicles Forecast: Vehicle Symposium Opinion Survey. Graham Environmental Sustainability Institute. http://graham.umich.edu/media/files/LC-IA-Final-Underwood.pdf
[193] Schiller, Robert, Randy Butler, and Mark Jensen. 2012. Kansas City Cross-town Improvement Project Evaluation: Results and Lessons Learned. TRB 2013 Annual Meeting. http://docs.trb.org/prp/13-0097.pdf

Traveler Information Systems (FRATIS), an ongoing FHWA project centered on studying and refining these features for improving freight movement.[194]

Protect Air Quality and Environmental Assets

Encourage investments that recognize the linkages between the social, economic, and natural fabric of the region.

Advanced technology vehicles and infrastructure offer the potential for significant reductions in air pollution and greenhouse gas emissions through shifts to electricity and renewable sources of energy such as solar power. Just as vehicle technology and emissions standards have dramatically reduced emissions rates for both automobiles and trucks, further movement to electric vehicles offers potential for significant further emissions reductions and health benefits. One study estimated that if future AVs in 2030 were electric and built smaller, then they could slash per-mile emissions rates by approximately 90% as compared to modern conventional vehicles.[195] Such a large reduction in per-mile emissions rates would be enough to overshadow even a many-fold increase in VMT. Other factors with positive effects include eco-driving and vehicle platooning (especially in freight). On the other hand, some of these benefits could be offset through additional VMT, faster highway speeds, and increased vehicle features. A study that combined the best research to date on these impacts and others found that vehicle automation could "plausibly reduce road transport GHG emissions and energy use by nearly half – or nearly double them – depending on which effects come to dominate."[196]

The short-term environmental impacts of mobility services are less clear. Past research of carsharing users in five North American cities indicated that the services reduced users' travel emissions by 4-18%,[197] but conclusive research on environmental impacts of other services is lacking. Use of solar power on roadways, sidewalks, and generation of energy through the kinetic energy of people or vehicles on roadways offers clean energy production directly through use of transportation. Lastly, trends in switching to e-commerce and telecommuting likely have environmental benefits. Although emissions changes from e-commerce as opposed to traditional shopping is a debated topic with some studies indicating more emissions from shopping online,[198] telecommuting and other opportunities to reduce travel are generally seen to have a positive impact on emissions.[199,200]

[194] Butler, Randy. 2012. Talking Freight: Freight Advanced Traveler Information System (FRATIS). Web, accessed March 16, 2017, https://www.fhwa.dot.gov/planning/freight_planning/talking_freight/jan182012transcript.cfm
[195] Greenblatt, Jeffrey, and Samveg Saxena. 2015. Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles. *Nature Climate Change* 5:860–863. doi:10.1038/nclimate2685
[196] Wadud et al. 2016. Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles. *Transportation Research Part A: Policy and Practice* 86(1):1-18. http://dx.doi.org/10.1016/j.tra.2015.12.001
[197] Martin, Elliot, and Susan Shaheen. 2016. Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities. http://innovativemobility.org/wp-content/uploads/2016/07/Impactsofcar2go_FiveCities_2016.pdf
[198] See, for example: http://dx.doi.org/10.1080/13504509.2015.1124471
[199] Williams, Anne. 2015. The Energy and Greenhouse Gas Emissions Impacts of Telecommuting and e-Commerce. Fraunhofer CSE. http://www.cleantechnotes.org/2015/04/23/the-energy-and-greenhouse-gas-emissions-impacts-of-telecommuting-and-e-commerce-2/
[200] Consumer Electronics Association. 2013. The Energy and Greenhouse Gas Emissions Impacts of Telecommuting and e-Commerce