



**REGIONAL TRANSPORTATION
TECHNOLOGY POLICY DOCUMENT:**
***Overview of Trends and
Policy Implications***

DECEMBER 2016



ACKNOWLEDGEMENTS

Project Advisory Committee

The Atlanta Regional Commission (ARC) would like to thank the advisory committee members who helped thoughtfully debate and shape this document.

- Troels Adrian, Director of Supply Chain Ecosystem Expansion, Metro Atlanta Chamber of Commerce
- Hillery Champagne, Director of Mobility Industry Expansion, Metro Atlanta Chamber of Commerce
- Jamie Fischer, Senior Performance Analyst, Georgia Regional Transportation Authority
- Gil Grodzinsky, Supervisory Modeler, Georgia Environmental Protection Division
- Andrew Heath, State Traffic Engineer, Georgia Department of Transportation
- Darrell Hobson, Manager of Intelligent Transportation Systems (ITS) Applications, Metropolitan Atlanta Rapid Transit Authority (MARTA)
- Dan Hourigan, Director of Transportation and Sustainability, Midtown Alliance
- Torrey Kirby, Director of Technology Applications, Metropolitan Atlanta Rapid Transit Authority (MARTA)
- Kaycee Mertz, Atlanta Branch Chief, Georgia Department of Transportation Office of Planning
- Eric Meyer, Planning Manager, Cobb County Department of Transportation
- Benoit Montreuil, Coca-Cola Material Handling & Distribution Chair, Director of Physical Internet Center, Director of Supply Chain & Logistics Institute, Georgia Institute of Technology
- Emil Runge, Chief of Staff to Councilmember Andre Dickens, City of Atlanta
- Quinton Spann, Planner, Georgia Department of Transportation Office of Planning
- Kari Watkins, Frederick L. Olmsted Junior Faculty Professorship & Assistant Professor, Georgia Institute of Technology

Report prepared by



With support from





Table of Contents

Executive Summary	i
Technology Trends.....	i
Implications of Technology Trends: An Assessment.....	ii
Timeframes of Expected Impacts	iv
Policy Implications	iv
Implementation: Leading Metro Atlanta into the Future.....	vi
1 Introduction.....	1
2 Key Technology Trends	2
2.1 Growth in Big Data and Connectivity	3
2.2 Advanced Vehicle Technologies	5
2.3 Technology-enabled Mobility Options.....	11
2.4 Freight Technologies and Logistics	15
2.5 Transportation System Management & Operations and Smart Infrastructure	19
2.6 The Concept of Smart Cities	23
2.7 Combined Trajectory of Trends / Future Scenarios	25
3 Assessment of Technology Trends	27
3.1 Societal, Private Sector, and Public Sector Impacts of Technologies	27
3.2 Assessment Framework and Analysis Methodology.....	29
3.3 Assessment Findings	30
3.4 Timeframes of Expected Impacts	32
3.5 Implications for Policy Development.....	34
4 Policy Implications	36
4.1 General Policy Implications	36
4.2 Atlanta Specific Policy Focus Areas	43
4.3 Implementation Mechanisms.....	48
5 Conclusion	50
Appendix A: Interview Participants and Sample Questions.....	51
Interview Participants	51
Sample of Interview Questionnaire	51
Appendix B: Trends Analysis	53
Appendix C: Bibliography	54

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: *Overview of Trends and Policy Implications*





EXECUTIVE SUMMARY

Transportation technologies are evolving rapidly. From the advent of autonomous vehicles (AVs), to increasingly ubiquitous data, mobile applications, and technology-enabled transportation services, the changes that technology are expected to have in transportation over the next ten to twenty years are vast. These new and emerging technologies will create potentially significant changes in how transportation systems need to be planned, managed, and operated into the future.

The Atlanta Regional Commission (ARC) has, through scenario planning, already begun to consider the effects that emerging technologies such as AVs and accelerated broadband might have on travel patterns. This report moves another step forward. It identifies and explores transportation technology trends, their potential impacts, and their policy implications, both generally and those specific to the Atlanta region. The result is intended to help support the Atlanta region in developing a regional transportation technology program to prepare for and take advantage of technology innovations in support of the region's goals.

Technology Trends

While there are numerous individual technologies in the marketplace or in development, this study identifies five overarching transportation technology trends that are likely to have significant impacts on travel and quality of life over the coming two decades:

1. **Increased widespread data and connectivity**, often described in the context of “big data” and the Internet of Things (IoT) —a foundation for most of the other technology trends.
2. **Advanced vehicle technologies**, including connected and autonomous vehicles (CVs and AVs) and electric and alternative fuel vehicles (EVs and AFVs).
3. **Adoption of new technology-enabled mobility options**, including connections between public transit and shared mobility, and new forms of “mobility on demand” (MOD).
4. **Developments in technologies affecting freight movement and logistics**, including new technologies for transporting goods such as drones, and changes in how technology is influencing logistics, such as through e-commerce and 3-D printing, as well as advancements in vehicle routing and efficiency, such as platooning of trucks.
5. **Advances in transportation system management/operations**, including mobile payment methods, real-time traveler information, and integrated corridor management, as well as smart infrastructure.

Figure ES-1 illustrates that these technology trends and advances are interrelated and linked together in several ways. Increasingly ubiquitous data, better connectivity, and the IoT form the foundation of other technology trends, such as CVs, new forms of MOD, and advances in transportation system management. Several of the trends are likely to come together in ways that reinforce each other. Automation and electrification of the vehicle fleet are mutually supportive, as AVs are easier to recharge with electricity than to refuel with conventional fossil fuels. Use of smartphones and accessible real-time data has supported new carsharing and



ride-hailing services, and offer the potential for MOD services that tie together all modes with mobile payment methods. Consequently, it is likely that in the future, autonomous electric vehicles will be utilized for MOD services while potentially being used to support urban goods distribution as well.

This confluence of technologies is often discussed in the context of “smart cities”, in which transportation is increasingly *instrumented, interconnected, and intelligent*.

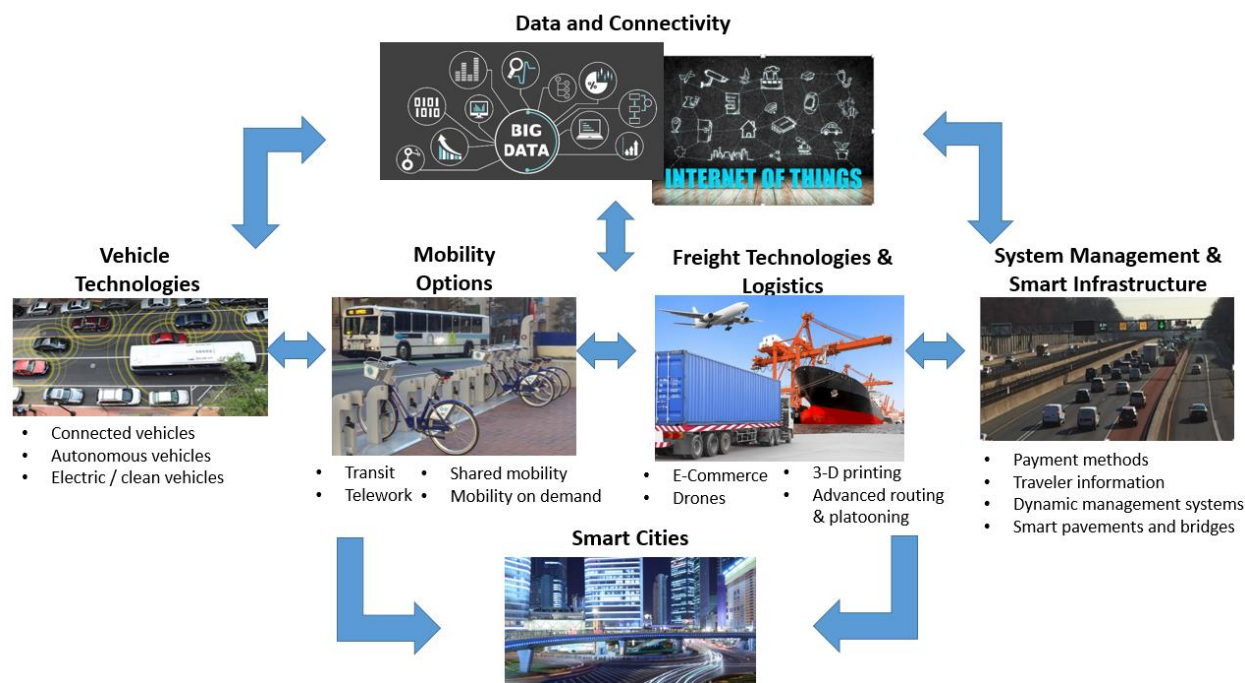


Figure ES-1. Technology trends in transportation.

Implications of Technology Trends: An Assessment

Looked at independently, each trend is significant. Combined, the implications may prove to be dramatic. Consequently, while it is useful to examine the impacts of individual trends, *it is essential to consider the combined impacts of the technology trends that are simultaneously advancing*.

The impacts can be explored in relation to a wide array of outcomes:

- **Travel** – including travel choices, travel costs, vehicle travel demand, traffic congestion, and travel reliability.
- **Societal** – including safety, environmental quality, equity, and land use/urban form.
- **Employment** – direct and indirect.
- **Infrastructure** – needs for infrastructure investments, the ability to monitor/manage infrastructure, and funding available to support investment needs.

For this study, an analysis framework was developed that addressed two key issues: the **direction of impact** (positive or negative), and **level of certainty of impact** (from highly certain to highly uncertain). The results are mapped in Figure ES-2 with the horizontal axis representing the direction/magnitude of impact and the vertical axis representing the level of certainty of the



impact. Impacts are located on the map based on judgement of expected impacts over the long-term (more than a 15-year period). Several impacts may be positive and/or negative, and these are represented with a horizontal bar spanning a range across the axis.

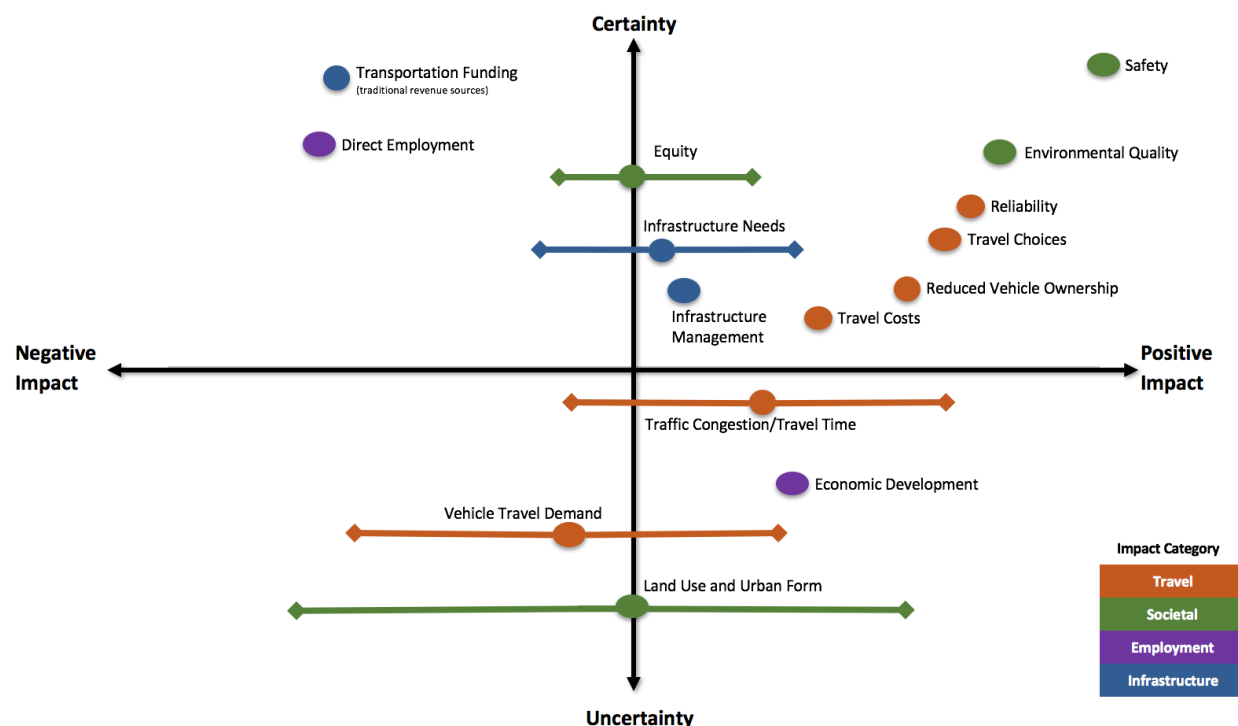


Figure ES-2. Implications of Transportation Technology Trends

The analysis highlights several key findings about the anticipated effects of technology trends in combination:

- *Safety* and *environmental quality* are anticipated to improve significantly, with a relatively high level of certainty. New vehicle technologies are anticipated to dramatically improve safety by reducing potential driver error, while electric vehicle and alternative fuel technologies will reduce air pollutant and greenhouse gas emissions.
- *Travel-related impacts* are quite varied and some of these impacts are difficult to assess with certainty. Travel choices and system reliability are expected to improve due to new shared mobility options, better data on real-time travel conditions, and improved travel routing optimization for passenger vehicles and freight. New shared mobility options and increased e-commerce are anticipated to reduce vehicle ownership and transportation costs. However, impacts on travel demand and ultimately traffic congestion and travel times are uncertain, with potential increases in vehicle miles traveled (VMT).
- Technology trends are likely to lead to *job losses in some industries*, but create the *potential for new jobs* in growing advanced technology industries and in relation to some new service models.
- Technology trends are likely to *reduce transportation infrastructure expansion needs* (and associated costs), but are also likely to *create some new infrastructure needs*. They also are likely to improve tracking of infrastructure conditions and performance, leading



to improved management of transportation system assets. However, shifts toward EVs and more energy efficient vehicles will *reduce the funding available for transportation* through traditional fuel-tax mechanisms.

- *Land use impacts* are generally the most uncertain effects, with potentially divergent trends toward increasing sprawl or support for more efficient development patterns.

Timeframes of Expected Impacts

Although the timeframes of technology implementation and their resulting impacts are subject to significant uncertainties, it is also useful to consider the potential impacts over a temporal scale. For several of the effects, Figure ES-3 provides a simplified assessment of the likely level of impacts along the spectrum of near-term (within 5 years), mid-term (5 to 15 years), and long-term (over 15 years). This temporal assessment shows that some of the most dramatic effects will likely require multiple technology advancements over a period of time. For instance, while connected vehicle technologies are anticipated to improve safety in the near-term, there are near-term challenges associated with a combination of advanced technology and conventional vehicles operating in mixed traffic, as well as interactions between vehicles, pedestrians, and bicyclists; consequently, the most dramatic effects will occur over time with larger scale shifts of the vehicle fleet toward AVs.

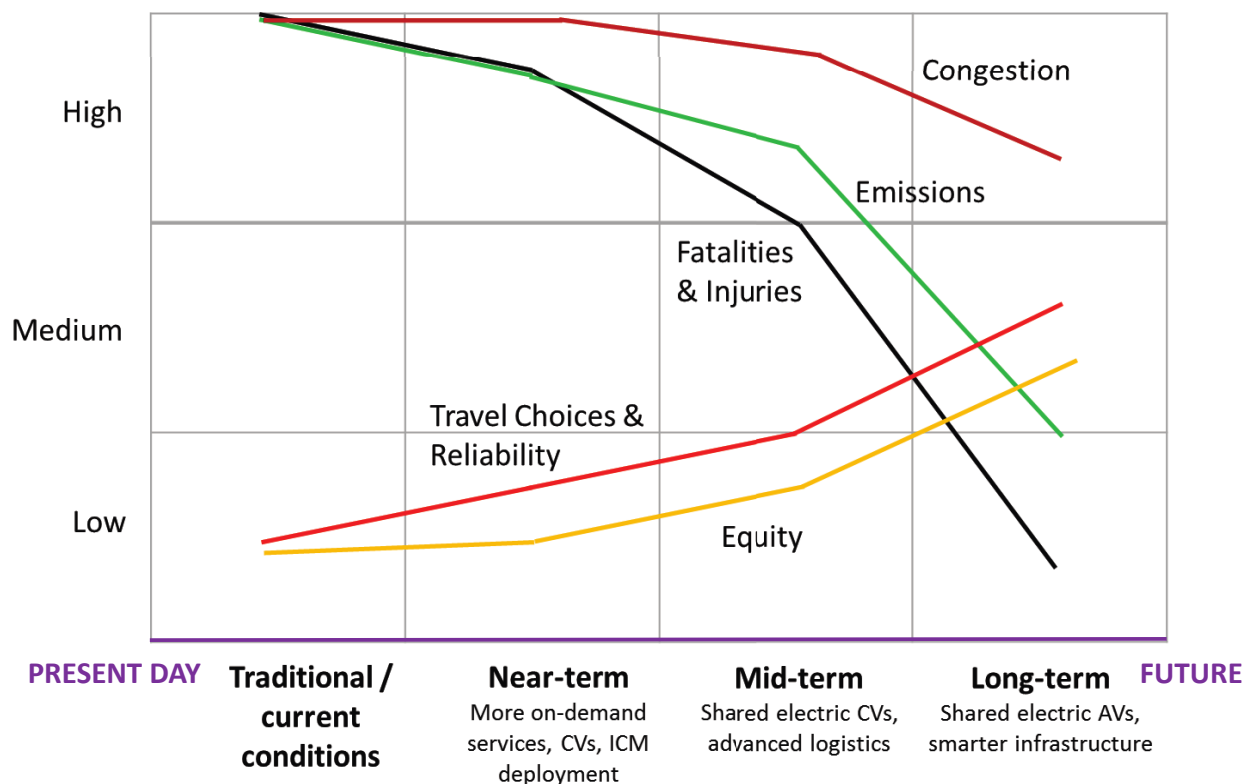


Figure ES-3. Estimated Timeframes for Outcomes

Policy Implications

The technology trends have a wide array of policy implications. Many are general and will require policies implemented at a national level or by states and regions around the country.



Some policies may be needed **to respond to new technologies or their impacts**. For instance, shifts towards more EVs and AFVs may result in a decline in traditional fuel tax sources, which in turn may require changes in transportation funding mechanisms. Other policies may be implemented specifically **to help shape positive outcomes or reduce the potential for negative impacts** associated with technologies. For instance, given the significant uncertainties associated with impacts on travel demand, policies could be designed to encourage high occupancy modes.

The regional policies identified in this report aim to achieve the three themes of ARC's "The Atlanta Region's Plan" (the long-range blueprint for metro Atlanta):

- Provide **world-class infrastructure** – Ensure a comprehensive transportation network, incorporating regional transit and 21st century technology.
- Build **a competitive economy** – Build the region as a globally recognized hub of innovation and prosperity; and develop a highly educated and skilled workforce, able to meet the needs of 21st century employers.
- Ensure the region is comprised of **healthy, livable communities** – Develop additional walkable, vibrant centers that support people of all ages and abilities; promote health, arts, and other aspects of a high quality of life.

This document highlights six key areas of technology policy focus recommended for the region:

1. **Data Sharing & Support:** Facilitate data sharing and integration among public agencies and between the public and private sectors.

2. **Infrastructure Planning and Investment:** Ensure appropriate investments in transportation infrastructure and technologies.

3. **Managing Travel Demand and Mobility Services:** Apply advanced technologies to actively manage travel demand and optimize system performance.

4. **The Physical Environment:** Develop policies that address changing needs in relation to use of public right-of-way, zoning, urban form, air quality, water supply, and other

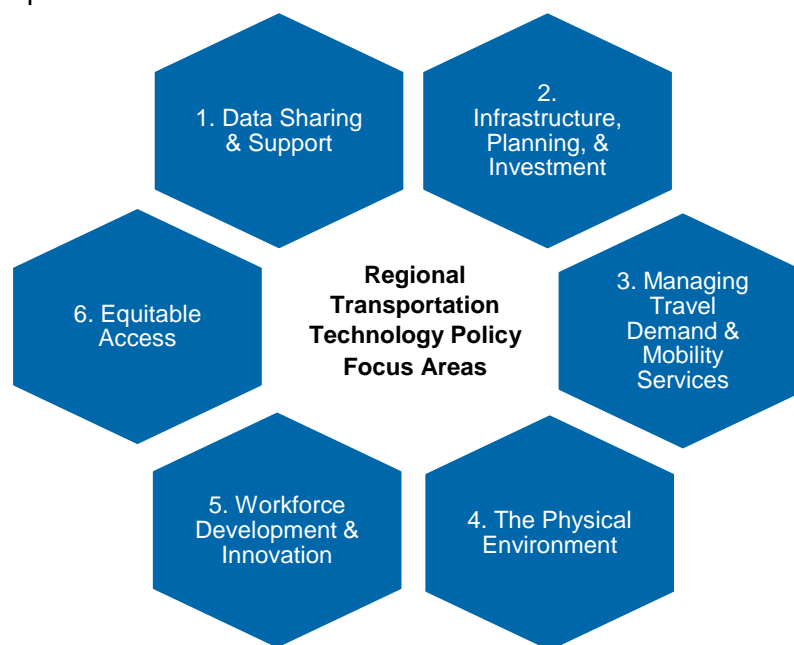


Figure ES-4. Technology Policy Focus Areas for the Atlanta Region



environmental factors.

5. **Workforce Development and Innovation:** Pursue efforts to make the Atlanta region an innovation hub in the development and deployment of transportation technologies.
6. **Equitable Access:** Support equitable outcomes for low-income and minority groups concerning rapidly changing transportation technologies.

These policies address the movement of both people and goods, and are linked together and can be mutually supportive of each other.

Implementation: Leading Metro Atlanta into the Future

Policy implementation is crucial to successfully address the impacts of technology changes and take advantage of the benefits of technology to support regional goals. The following are three implementation mechanisms that are recommended to connect the six focus areas above.

- **Fund pilot programs to advance technology deployment.** Pilot programs can bring together multiple concepts, such as mobility applications, data sharing, and support for equitable access, and can be used to test solutions and innovate in specific areas.
- **Develop an on-going regional forum or task force around transportation technology innovation.** This group would facilitate collaboration across industries and sectors and have a goal of advancing the Atlanta region as a hub of innovation. This group could also provide feedback or input to pilot projects.
- **Develop partnerships and visionary concepts to help prepare the region to compete for potential future federal discretionary grants or secure private sector funding.** Over the past several years, there have been a number of significant federal discretionary grants focused on transportation technology applications. Development of Atlanta region-specific concepts and test-beds would be useful to help generate regional support for and partnerships necessary to compete effectively for funding.

These efforts will create the foundation for the Atlanta region to be a leader in advancing transportation technology and to shape the future of the region in light of the potentially groundbreaking impacts of technology trends.



1 INTRODUCTION

This Regional Transportation Technology Policy Document provides insight into identified key technology trends within the field of transportation and their related policy implications both broadly and for the Atlanta region. As such, this document can be viewed as an important step in the development of a comprehensive strategic plan to address technology-related issues.

This document synthesizes approximately 50 sources identified as part of an annotated bibliography for this effort, as well as 13 interviews with thought leaders from private industry, the public sector, and academia in different fields of knowledge related to transportation. This information provides the foundation for a trend analysis, and identification of *general and Atlanta region-specific policy implications*. The identified general policy implications include policies, regulations, or other actions requiring implementation at a national level, either by the federal government or by states or local governments across the country. For the Atlanta region, the document identifies recommended areas of policy focus to not only respond to the consequences of rapidly changes transportation trends, but also to proactively shape the future outcomes of those trends in support of the region's goals.

The remaining sections of the document are organized as follows:

- **Section 2: Key Technology Trends** identifies key technology trends identified through a literature review and interviews with experts in the field.
- **Section 3: Assessment of Technology Trends** presents a framework that was used to assess the impacts of technology trends, assesses the trends, and discusses timeframes of their expected effects.
- **Section 4: Policy Implications** identifies general and Atlanta region-specific policy implications and possible implementation steps.
- **Section 5: Conclusion** ends the document with a statement of why this effort is so important.
- **Appendix A: Interview Participants and Sample Questions** presents the list of experts interviewed and a sample of the questionnaire used.
- **Appendix B: Trends Analysis** provides a more detailed assessment of the impact and level of certainty associated with individual trends.
- **Appendix C: Bibliography** lists the references cited throughout this document.



2 KEY TECHNOLOGY TRENDS

The transportation systems around which society has been built are on the verge of a significant transformation. Just as computers and smart phones have transformed many aspects of daily life, businesses, health care, and social interactions, new technologies are being developed and deployed that are likely to dramatically change the way in which people and goods are moved and the roles of transportation agencies in managing transportation services and system investments.

Five overarching transportation technology trends are likely to have significant impacts on travel and quality of life over the coming two decades, as shown in Figure 2-1.

1. Increased widespread data and connectivity — the foundation for most of the other technology trends.
2. Advanced vehicle technologies, including connected and autonomous vehicles (CVs and AVs) and electric and alternative fuel vehicles (EVs and AFVs).
3. Adoption of new technology-enabled mobility options, including connections between public transit and shared mobility, and new forms of “mobility on demand” (MOD).
4. Developments in technologies affecting freight movement and logistics, including new technologies for transporting goods such as drones, and changes in how technology is influencing logistics, such as through e-commerce and 3-D printing, as well as advancements in vehicle routing and efficiency, such as platooning of trucks.
5. Advances in transportation system management/operations, including mobile payment methods, real-time traveler information, and integrated corridor management, as well as smart infrastructure.

The arrows in Figure 2-1 illustrate that the five trends are linked together in several ways and come together to reinforce each other. In particular, big data and growing connectivity, often referred to as the Internet of Things (IoT), are enablers of many other technologies, business models, and services. For instance, enhanced connectivity is a basis for connected vehicle (CV) technologies and increasingly available and detailed data on vehicle movement and person movement is leading to enhancements in multimodal transportation system management. As the trends continue to come together, they can support the concept of “smart cities,” where transportation systems are increasingly instrumented, interconnected, and intelligent because they are tied together by information and communication technologies (ICT) that process a plethora of data.

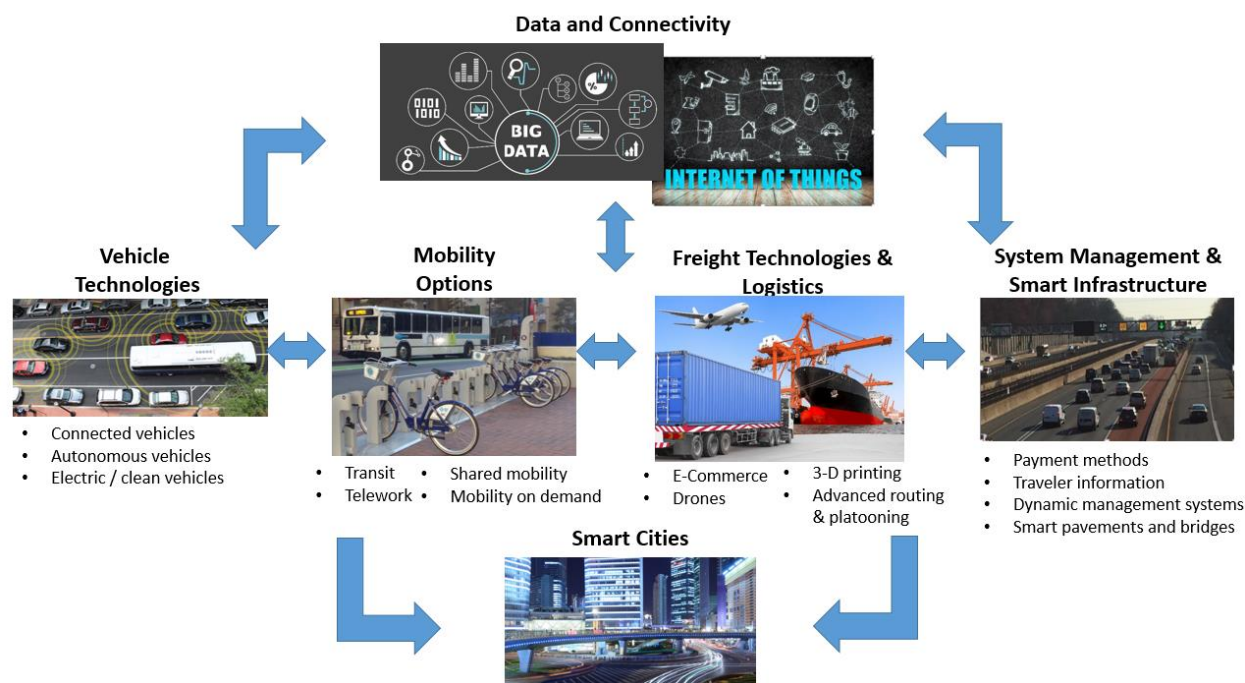


Figure 2-1. Technology Trends in Transportation

This chapter describes these technology trends, building on the results of a literature review, including recent published documents and web sources, and findings from interviews with thought leaders and experts from private industry, the public sector, and academia (see Appendix A).

2.1 Growth in Big Data and Connectivity

Every day, more objects, including vehicles, are connecting to the internet—it is expected that over 50 billion devices will be connected by 2020.¹ Fueled by the Internet of Things (IoT), innovative applications and enhanced software and hardware are being developed and integrated into all elements of the transportation network (e.g., users, vehicles, and infrastructure), enabling a suite of vehicle-to-anything (V2X), bicycle-to-infrastructure, pedestrian-to-infrastructure, and infrastructure-to-agency communication systems/applications.



Data and connectivity have exploded over recent years, as people—through smartphones, smart watches, and other wearable products—are increasingly collecting and sharing data about their location, patterns of activity, and facets of information such as health indicators. Meanwhile, products and objects—from home appliances, to smart thermostats, to vehicles—are increasingly connected to the internet, allowing people and the objects themselves to

¹ 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/>



monitor conditions, share information, communicate with each other, and adapt to changing needs. Commonly called “Big data”, the explosion of information allows much more precise targeting of information as well as predictive capabilities. Meanwhile, the ever increasing use of “sensors and actuators embedded in physical objects...linked through wired and wireless networks”, often discussed as IoT, are enabling a transformation of transportation, as well as the way in which people interact with their homes, vehicles, and each other.² From sensors mounted on buildings and on roads to wireless signals on smartphones, data is constantly emitted and collected by an ever-wider array of products connected to the Internet.

For transportation specifically, data and connectivity are enablers of many advances in vehicles, as well as transportation services, and system planning and operations. Increased access to detailed data is allowing planners and system operators, as well as the public, to see where and when congestion occurs. It enables a more efficient system for freight delivery and helps transit agencies understand their riders. As an example of value in logistics, one private sector company, Under Armour®, currently has visibility to the workout habits, product preferences, and buying the data history of more than 140 million individuals. Through big data analysis, Under Armour is providing faster deliveries of products and optimizing its supply chain to meet consumer demand at a near real-time pace.³

The transportation-related applications of big data are broad and can be useful in reducing traffic congestion, improving reliability, and increasing efficiency in the transportation system. In Israel, for example, a toll system on a 13-mile fast lane between Tel Aviv and Ben Gurion Airport that calculates the cost of the toll based on the number of cars on the road is using real-time data on traffic conditions. Through advanced telematics and large datasets, the system is able to manage congestion by steering demand.⁴ Similar technologies are being used in the U.S., such as on express lanes on Interstates 85 in Georgia that use dynamic tolls based on the volume of traffic and the managed lanes being constructed on Interstates 75 and 85.⁵ In Germany, railway companies are using big data to improve the efficiency of cargo trains. Through data, the companies are determining which tracks have the most, or least, capacity, and are able to better plan delivery itineraries and reduce delays.⁶ Transport for London (TfL), the city’s transit manager, uses data for planning services and for providing information to customers. Through data collected on fare cards, TfL has a clear picture of where customers are traveling and which modes they are using.⁷

² Chui, Michael, Loffler, Markus, and Roberts, Roger. (2010). *The Internet of Things*. McKinsey Quarterly. Available at: <http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things>.

³ Lori Mitchell-Keller (May 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/>

⁴ Neumann, Carl-Stefan. (July 2015). “Big Data Versus Big Congestion: Using Information to Improve Transport.” McKinsey and Company. Available at <http://www.mckinsey.com/industries/infrastructure/our-insights/big-data-versus-big-congestion-using-information-to-improve-transport>

⁵ Managed Lanes . “Atlanta Regional Managed Lanes Implementation Plan.” Available at http://www.dot.ga.gov/BuildSmart/Studies/ManagedLanesDocuments/MLIP/MLIP01_Report_Exec_Summary.pdf

⁶ Neumann, Carl-Stefan. (July 2015). “Big Data Versus Big Congestion: Using Information to Improve Transport.” McKinsey and Company. Available at <http://www.mckinsey.com/industries/infrastructure/our-insights/big-data-versus-big-congestion-using-information-to-improve-transport>

⁷ Marr, Bernard. (March 2015). “How Big Data and the Internet of Things Improve Public Transit in London.” Forbes. Available at: <http://www.forbes.com/sites/bernardmarr/2015/05/27/how-big-data-and-the-internet-of-things-improve-public-transport-in-london/#2dbe43603ab3>.



Big data has important applications beyond operations that can be used to better understand travel behavior, which is important in planning future investment and service needs. The City of Boston has partnered with the 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. Uber is one many Transportation Network Company (TNC) companies operating globally in a car sharing model where the TNC connects a paying passenger to a driver in their own non-commercial vehicle via phone app. Social media is also being considered as a medium to understand the public's activity patterns. Ultimately, "big data provides a way to build and test theories about cities and advance our ability to model the urban area and the behavior of households, firms, and institutions within it."⁸

Enhanced connectivity has also enabled the rise of CV technology, on-demand and dynamic transit, and shared use mobility. Motor vehicles increasingly are allowing for private companies to gather more information and for users to stay connected. Both Google and Apple now have applications mounted in dashboards in select cars. Deemed the "ultimate copilot," Apple CarPlay allows users to "get directions, make calls, send and receive messages, and listen to music" simply by connecting their iPhone to the dashboard and using Siri voice commands.⁹ Similarly, Android Auto, powered by Google, integrates Android technology into vehicles' digital platform and provides the same features as Apple CarPlay.¹⁰ Both of these systems illustrate the move toward increasingly connected vehicles.

2.2 Advanced Vehicle Technologies

Technologies used in motor vehicles – 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.



Over the past several years, the automobile and technology industries have made significant leaps in bringing computerization and wireless capabilities into motor vehicles. Such improvements have revolved around technologies that allow sensors and software to communicate with one another and to replace some or all of the human function in driving. The National Highway Traffic Safety Administration (NHTSA) notes that distinct but related streams of technological development are occurring simultaneously (including in-vehicle crash avoidance systems, connected vehicle communications and self-

⁸ French, Steve, Camille Barchers, and Wenwen Zhang. (2015). Moving Beyond Operations: Leveraging Big Data for Urban Planning Decisions. Massachusetts Institute of Technology 14th International Conference on Computers in Urban Planning and Urban Management. Retrieved from http://web.mit.edu/cron/project/CUPUM2015/proceedings/Content/pss/194_french_h.pdf.

⁹ Apple. (2016). Apple CarPlay. <http://www.apple.com/ios/carplay/>.

¹⁰ Android. (2016). Android Auto. <https://www.android.com/auto/>



driving vehicles).¹¹ These efforts are different paths of technology development efforts leading towards vehicles that are both connected and autonomous, that can sense their environment and share information with all elements of it.

Meanwhile, the industry is shifting toward increased adoption of EVs and AFVs. Over the coming years, continued advancements in EV and other clean vehicle technologies are expected to yield potentially significant shifts from fossil fuel based vehicles to use of sustainable energy, with development required for alternative fuel infrastructure. In September 2016, NHTSA produced Federal Policy for Autonomous vehicles, an effort to look at existing regulations and what adjustments need to be made to formulate new regulations related to road and driving in the context of autonomous vehicles¹².

2.2.1 Connected Vehicles

Connected vehicle features allow vehicles to communicate with each other (referred to as vehicle-to-vehicle or V2V communications), as well as communications between vehicles and roadway infrastructure, such as traffic signals and tollbooths (referred to as vehicle-to-infrastructure or V2I communications).¹³ In order to achieve the desired level of testing and subsequent operation of CVs, the U.S. Department of Transportation (USDOT) is advancing use of Dedicated Short Range Communication (DSRC) radios and a portion of wireless bandwidth that the Federal Communications Commission (FCC) has dedicated to transportation applications to support communications among vehicles to maximize safety. Furthermore, the V2I Deployment Coalition Technical Working Group and the American Association of State Highway and Transportation Officials (AASHTO) have developed a “Connected Vehicle Deployment Challenge” for all 50 states to equip at least one corridor with DSRC infrastructure to broadcast Signal Phase and Timing (SPaT) information by January 2020. In addition, NHTSA is developing regulations to mandate all new light-duty vehicles contain this equipment.

Several deployment scenarios within the “National Connected Vehicle Field Infrastructure Footprint Analysis” illustrate how state and local agencies might use CV technologies¹⁴. In general, each scenario entails the deployment of vehicle and back-office applications and systems that will enable communication between and across vehicles and infrastructures. Specifically, the document examines the following scenarios:

1. Urban Deployments
2. Rural Deployments
3. Multi-state Corridors
4. DOT System Operations and Maintenance
5. Commercial Vehicle and Freight Systems
6. International Land and Border Crossings

¹¹ National Highway Traffic Safety Administration (2013). “Preliminary Statement of Policy Concerning Automated Vehicles.”

¹² National Highway Traffic Safety Administration (2013). “Preliminary Statement of Policy Concerning Automated Vehicles.” Available at: <https://one.nhtsa.gov/nhtsa/av/av-policy.html>

¹³ Intelligent Transportation Systems Joint Program Office, Connected Vehicle Research website, available at: http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.htm

¹⁴ National Connected Vehicle Field Infrastructure Footprint Analysis (2013). Available at: <http://stsmo.transportation.org/Documents/Task 6a AASHTO CV Footprint Deployment Scenarios v2.pdf>



7. Fee Payments

The scenarios above highlight potential trends in the CV-deployment path, as many agencies are evaluating and testing CV-enabled applications and systems that directly relate to such scenarios. Table 2-1 summarizes some of these applications and systems, and links each to one of the seven scenarios. Most applications and systems could benefit more than one scenario (and potential users), even if not listed in the table, depending on the deploying agency's desired scope and objectives.

Table 2-1. CV-enabled Deployment Scenarios

Application/Systems	Scenarios						
	1	2	3	4	5	6	7
Applications							
Red Light Violation Warning and Stop Sign Violation	X	X					
Driver Gap Assist at Signalized Intersections and Stop Signs	X				X		
Motorist Advisories and Warnings	X	X	X				
Reduced Speed / Work Zone Warnings			X				
Truck Wireless Roadside Inspection			X		X	X	
Truck E-Screening and Virtual Weigh Stations			X		X	X	
Smart Truck Parking			X		X	X	
Wireless Fee Payment	X	X	X		X		X
Systems							
Active Traffic Management	X	X	X				
Advanced Traveler Information System	X	X	X				
Multimodal Intelligent Traffic Signal Systems	X						
Integrated Dynamic Transit Operations	X		X				
Integrated Dynamic Multimodal Operations	X					X	
Origin-Destination, Traffic Model Baseline & Predictive Traffic Studies	X					X	
Eco-Signal Operations	X						
Dynamic Eco-Routing	X		X		X	X	
Work Zone Traveler Information			X	X			
Enhanced Maintenance Decision Support Systems			X	X			
Probe-based Pavement Maintenance				X			
Maintenance and Fleet Management Systems				X			
Freight Advanced Traveler Information Systems (FRATIS)					X	X	

Source: U.S. Department of Transportation, Intelligent Transportation Systems Joint Program Office, "National Connected Vehicle Field Infrastructure Footprint Analysis: Deployment Scenarios." Final Report, December 27, 2013.

Recognizing the time it will take for the vehicle fleet to turn over, there are a number of technologies, mainly developed by the private sector, that are readily available and can convert vehicles that satisfy minimum requirements into a connected and/or smart vehicle. Such technologies can influence the performance of a transportation system from both the user and agency perspective. For instance, Sirius XM Connected Vehicle Services Inc. provides



telematics services to enhance safety, security and convenience services for drivers and end-to-end turnkey solutions for automakers. Their equipment's capability ranges from low-level transfer of information (e.g., Basic Safety Message Part I data) to full integration with the vehicle network via a Controller Area Network (CAN) connection and advanced collection, transfer and display of information through on-board equipment that enables a suite of V2I and V2V applications. Another example is Weathercloud, which converts any equipped vehicle into a mobile weather station that collects ground-truth weather and road condition data through proprietary weather sensors, and combines it with other available information (i.e., road weather information system (RWIS) data).¹⁵ Finally, Mobileye provides the user a smart camera located on the front windshield inside the vehicle. Through it, the system detects traffic signs, measures the distance to vehicles, lane markings, and pedestrians, and provides alerts to the driver when needed.

2.2.2 Autonomous Vehicles

Autonomous vehicles operate without a human driver, and semi-autonomous features—enabled by sensors, cameras, radars, and communications technologies—facilitate vehicles to operate with limited human interaction. NHTSA has defined five levels in a progression moving toward increased autonomy: from Level 1 (driver-assistance for a specific function like steering or accelerating) to Level 5 (fully autonomous in every driving scenario, including extreme environments like dirt roads). Given advances in communications and vehicle technologies, questions surrounding AV technologies are centered less on whether these advances will occur but on when and how implementation will impact transportation.

New car models increasingly include semi-autonomous features such as:

- Adaptive cruise control, which automatically adjusts the vehicle speed to maintain a safe distance from vehicles ahead.
- Parking assist systems that allow cars to steer themselves into parking spaces.
- Lane departure warning systems, which warn a driver when a vehicle begins to veer out of its lane, and lane-keeping systems, which automatically take steps to ensure the vehicle stays in its lane (unless a turn signal is on in that direction).
- Systems that break by themselves in an emergency to avoid a crash.

Some companies have gone further by developing self-driving vehicles that can navigate many 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.¹⁶ 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.¹⁷ Tesla motors' has announced that its Model S vehicles will be outfitted with the hardware

¹⁵ WeatherCloud. <http://weathercloud.co/>

¹⁶ Consumer Electronics Association, "Driverless Cars on the Rise" (2014), January 5. Available at: <http://www.ce.org/i3/Features/2014/January-February/Driverless-Cars-on-the-Rise>

¹⁷ Google, Self-Driving Car Project, <http://www.google.com/selfdrivingcar/>, accessed on August 4, 2016.



needed for full self-driving capability.¹⁸ 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.¹⁹

Complementary trends in shared rides and vehicles may lead us from vehicles as an owned product to an on-demand service. As AVs gain 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 be affected. Additionally, the passenger compartment of vehicles and how people utilize them may be transformed.

2.2.3 Electric and Alternative Fueled Vehicles

Increasingly EVs and AFVs are becoming more commonplace in the market. This is likely to increase in the future, as regulators are turning to EVs and AFVs for a solution to the growing concerns over the environmental impacts of gasoline-powered vehicles as well as the reality that the U.S. does not have an endless supply of oil. 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 convenient for the American family as gasoline-powered vehicles by 2022."²⁰ Furthermore, California's SB 1275, the "Charge Ahead California Initiative", lays out a plan to put one million electric vehicles on the state's roads by 2023 to help California meet its greenhouse gas (GHG) emissions reduction targets. The goal of the law is to establish a self-sustaining California market for zero-emission and near-zero-emission vehicles in which these vehicles are a viable mainstream option for individual vehicle purchasers, businesses, and public fleets, and to increase access to these vehicles for disadvantaged, low-income, and moderate-income communities and consumers.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."²² Under the vision of Tesla's founder and CEO, Elon Musk, 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

¹⁸ USA Today, "Tesla announces fully self-driving cars." October 20, 2016, <http://www.usatoday.com/story/tech/news/2016/10/19/tesla-announces-fully-self-driving-fleet/92430638/>, accessed on December 20, 2016.

¹⁹ Hull, Dan, Jeff Plungis, and David Welch. (June 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>.

²⁰ U.S. Department of Energy (2016). "About EV Everywhere." U.S. Department of Energy. Available at: <http://energy.gov/eere/everywhere/about-ev-everywhere>.

²¹ SB-1275 Vehicle retirement and replacement: Charge Ahead California Initiative. Available at: http://leginfo.ca.gov/faces/billTextClient.xhtml?bill_id=201320140SB1275.

²² Ramsey, Mike and Cassandra Sweet (August 2016). "Tesla and SolarCity Agree to \$2.6 Billion Deal." *The Wall Street Journal*. Available at: <http://www.wsj.com/articles/tesla-and-solarcity-agree-to-2-6-billion-merger-deal-1470050724>



\$35,000) and long range (i.e., around 200 miles) EV models, including Chevy's Bolt, Nissan's Leaf, and Tesla's Model 3. These new generations of EVs will help promote alternate-fueled vehicles and may significantly increase EV market share. New forms of transportation infrastructure to support EVs have been conceptualized, such as electrified roadways, which may use conductive overhead catenary lines, conductive in-road rails, or inductive in-road pads or strips.²³

A National Research Council report suggested that an 80 percent reduction in light-duty vehicle petroleum use by 2050 potentially could be met through several combinations of technologies, including increased production and use of biofuels and/or large-scale deployment of compressed natural gas (CNG) vehicles, battery electric vehicles, or fuel cell electric vehicles (FCEVs). 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.²⁴ Consequently, extensive new fuel infrastructure would be needed for FCEVs and new supply lines for CNG vehicles.

2.2.4 Other Vehicle and Modal Innovations

New types of vehicles and modes of transportation also have been proposed or are being developed as prototypes. The American motor vehicle manufacturing company Local Motors has several projects underway on next generation transportation innovations. Olli, described by the company as "your friendly neighborhood mobility solution," is an electric powered, self-driving vehicle for shared urban travel. The company is also experimenting with 3-D printed cars.²⁵

New modes of transit are also being developed to overcome the limitations of congestion in an urban environment. China is developing a prototype of the Transit Elevated Bus, a 72 feet long and 26 feet wide bus that traverses over congested streets (see photo to the right). A full city test run is expected to occur in 2017.²⁶ Another mode of transit envisioned for the near future is Personal Rapid Transit (PRT), currently being promoted in London and in Abu Dhabi's planned city Masdar. PRTs consist of electric, autonomous pod-like vehicles that run on either specified closed track corridors (as is currently being used in Masdar and London's Heathrow Airport) or regular streets (as it is planned for London) offer a



Source: Credit Luo Xiaoguang/ Xinhua, via Associated Press

²³ Natural Renewable Energy Laboratory (2016). E-Roadway Animation. Retrieved in August 2016 from: http://www.nrel.gov/transportation/e-roadway_animation.html

²⁴ National Research Council of the National Academies, *Transitions to Alternative Vehicles and Fuels*. Washington, DC: National Academies Press, 2013.

²⁵ Local Motors, <https://localmotors.com/>.

²⁶ Buckley, Chris and Emily Feng (August 2016). "China's Straddling Bus, on a Test Run, Floats Above the Streets." *The New York Times*. Available at: http://www.nytimes.com/2016/08/05/world/asia/china-elevated-bus-teb.html?_r=0



glimpse of what a transportation could look like in the future.²⁷ A Chinese company has displayed a people mover drone, named eHang, at the 2016 Consumer Electronic Show.²⁸

The Hyperloop is 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.²⁹

Next generation technologies are also being designed for freight transport. The Freight Shuttle, initially developed by the Texas A&M Transportation Institute (see picture to the right), moves 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.”³⁰



Source: Freight Shuttle International.

While each of these efforts is exciting, experience suggests that the value and adoption of these new modes is highly uncertain. 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. Similarly, it is unclear whether these proposed advanced technology modes will achieve significant levels of adoption.

2.3 Technology-enabled Mobility Options

In addition to changes in vehicles themselves, technology advances — particularly driven by smartphones and access to Big Data, including crowd-sourced data — are creating new and enhanced mobility options, including new forms of shared mobility, enhancements in traveler information and choices, and new business models for providing transportation services.

Together with vehicle technology enhancements, these changes could be transformational. Published by Columbia University’s Earth Institute, “Transforming Personal Mobility” presents a framework for the future of transportation. The authors argue that “a wide range of technology and business enablers are emerging that, when combined in innovative ways, promise to transform the way people and goods move around and interact economically and socially.” Through modeling, the research finds that the combination of the “mobility internet” and self-driving, shared, and purpose-specific vehicles running on advanced propulsion systems (e.g., alternative energy and power sources) will bring about a better and more efficient transportation system. Within the framework presented, travelers depend on a fleet of driverless vehicles that they can summon on their smartphones, helping them move towards a world free of vehicle

²⁷ Masdar City, <http://www.masdar.ae/>.

²⁸ Goldman, David. (January 2016). Human-carrying drone debuts a CES. Retrieved on August 2016 from: <http://money.cnn.com/2016/01/06/technology/ces-2016-ehang-drone/>

²⁹ Hyperloop One, <https://hyperloop-one.com/>.

³⁰ Freight Shuttle International, <https://www.freightshuttle.com/>.



ownership.

2.3.1 Shared Mobility Options – Ridesharing and Carsharing

Technology has supported the emergence of a new shared use economy, as exemplified by digital media in which people access and pay for online commodities such as music, movies, and books without ever obtaining physical ownership of them, as well as shared resources services like Airbnb, which allows people to rent out their homes or apartments. In the transportation realm, shared use mobility, such as carsharing, bikesharing, dynamic ridesharing, ridesourcing, and on-demand transit, have gained prominence in recent years.

Through the shared use economy, people have access to a wide array of travel options, such as on-demand transportation network companies, private transit, public transit, carsharing, and bikesharing. While many of these concepts emerged years ago (for instance, bikesharing first emerged in the 1960s in Amsterdam), their growth is being enabled due to smart phones and communications technology that ease reservations, vehicle tracking, and payment for services, according to the Transportation Sustainability Research Center at the University of California Berkeley.³¹

These options have seen considerable growth in recent years. Over the past 15 years, carsharing in the U.S. has grown from a largely subsidized, university research-driven experiment into a for-profit enterprise, with companies such as Zipcar (owned by Avis Budget Group), car2go (owned by Daimler), Enterprise CarShare, and Hertz 24/7 controlling more of the U.S. market.³² 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 448,600 carshare members in the U.S. in 2010 to nearly 1.34 million members in 2014.³³

While these figures are still a small share of the overall market, as new options emerge, owning a car, especially in large cities, is becoming less of a necessity. However, trends toward urban living and the desire to save money on transportation, which is one of the largest household expenses, may be encouraging growth. The rise of shared use mobility may be a supporting factor in the recent reductions in vehicle travel seen by millennials, as between 2009 and 2012 car ownership declined 9 percent and average vehicle miles traveled (VMT) for those aged 16 to 34 dropped 23 percent.³⁴

Some companies are providing services via apps that connect vehicle information with user devices. One San Francisco-based company, Automatic, has built a Bluetooth device that connects the user’s car diagnostics system to covert your car into a smart car. The user interacts with the system via an app to track driving statistics such as miles fuel economy, miles

³¹ Institute of Transportation Studies Berkeley, Transportation and the Sharing Economy. Available at: <http://its.berkeley.edu/btl/2014/winter/sharedmobility>

³² Brown, Chris (2015), “CarSharing: State of the Market and Growth Potential,” Auto Rental News, March/April, available at: <http://www.autorentalnews.com/channel/rental-operations/article/story/2015/03/carsharing-state-of-the-market-and-growth-potential.aspx>

³³ 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>

³⁴ Filler, Larry and Marc Oliphant. “Shared Use Mobility: The Next Big Thing in Transportation.” Eno Transportation Center. Available at: <https://www.enotrans.org/eno-brief/shared-use-mobility-the-next-big-thing-in-transportation>.



driven or to locate where the car is parked. All of this information can be used to improve driving performance or itemizing business trips. This service can also support phone apps such as Amazon's Alexa, Nest, Pebble and more. One supported app, called Unmooch, is a car sharing app. 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 through a payment app to alert the friends to their share of the bill.³⁵ New service models have also come into existence. RelayRides enables people who own cars to let others rent their vehicle while not in use; the service provides free parking at airports in exchange for letting others rent the vehicle while the owner is away.³⁶

"Shared Mobility: Current Practices and Guiding Principles" by Shaheen, Cohen, and Zohdy presents an introduction to shared mobility. The authors discuss a number of shared mobility service models, organizing these models into two broad categories: Core and Incumbent Services (e.g. car rental, limos, paratransit, and public transit.) and Innovative Services (e.g. bikesharing, carsharing, e-hail, and ridesourcing). Services such as vanpool and carpool fall in their own in-between category. The authors note "shared mobility is changing the perception of transportation in the United States and worldwide, spawning new business models and influencing individual transportation choices and behavior."

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 (MTC), for example, is teaming with Carma,³⁷ Scoop,³⁸ and Lyft³⁹ to help encourage carpooling.⁴⁰ For a region plagued by severe congestion, carpooling offers many rewards to commuters. Despite the benefits of carpooling, it can be difficult for drivers and riders to find commute partners. However, MTC's partnership with the technology companies aims to reduce that difficulty. Barbara Laurensen, MTC's Rideshare Program project manager noted, "With each new carpool app, we see technology removing barriers to carpooling through automated communication, automated payment, transparent meet-up logistics and flexible arrangements."⁴¹

2.3.2 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 and enabling improved connections among modal choices. By integrating the two travel modes, the first-mile/last-mile issue is reduced, and travelers may be more likely to forgo a private vehicle in favor of a shared mode. Stiglic, Agatz, Savelsbergh, and Gradisar's "Enhancing Urban Mobility: Integrating Ride-sharing and Public Transit" delves into this topic, analyzing the benefits of an integrated system as well as the ride-matching technology required to support it. The authors argue that ridesharing and public transit

³⁵ Automatic website, available at: <https://www.automatic.com/apps/>

³⁶ RelayRides web site, available at: <https://relayrides.com/>

³⁷ Carma, <https://www.gocarma.com/>.

³⁸ Scoop, <https://www.takescoop.com/>.

³⁹ Lyft, <https://www.lyft.com/>.

⁴⁰ 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>.

⁴¹ Metropolitan Transportation Commission. (2016). "There's an App for That."



complement each other. Where ridesharing can serve as a “feeder system that connects less densely populated areas to public transit,” the public transit system “extend[s] the reach of ridesharing and reduce[s] the detours of the drivers.” In their analysis, the authors envision a centralized system that creates matches between riders and drivers, where a driver can choose to drive the rider to a transit stop or all the way to their final destination. The study finds that integrating ridesharing and transit is beneficial, increasing the average number of matched riders by 17 percent. Similarly, the length of driver detour is reduced by just over 1 percent. As the results indicate, not only are travelers more connected through an integrated system, but the negative environmental impacts of driving are reduced.

Applications like NextBus already use GPS and wireless networks to communicate the arrival time of buses at bus stops. Other mobile applications provide routing and traffic guidance, and information on parking and construction, and real-time transit arrival times. An example of this is Moovit, 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.

In their report, “Urban Mobility at a Tipping Point,” Bouton, Knupfer, Mihov, and Swartz explain that beyond building transit, cities are also bringing existing transit systems into the 21st century. Cities are “digitizing” their transit systems and “trying new mobility-on-demand models”. Helsinki has attempted to make personal cars obsolete by 2025 through its Mobility as a Service (MaaS) plan, which creates a centralized smartphone application — run by a public utility, rather than by multiple private-sector companies — for booking and paying for bus, train, taxi, bicycle, and carsharing trips. Helsinki’s ambitious plan seeks to build an on demand system that would allow users to “purchase mobility in real time, straight from their smartphones.”⁴² This approach is a potentially suitable response to unifying the increasing number of “smart services,” allowing all available modes of transportation to communicate and work together to enhance their services, while providing the user a single tool to access their services. Similarly, the Société de Transport de Montréal has established an integrated mobility program that “promotes a smart combination of individual means of transportation (walking, cycling, driving) with collective modes (bus, metro, taxi, shared taxibus, carpooling, and carsharing) for mobility needs.”⁴³ The agency has formal agreements with several transportation providers in the city, giving travelers better fares and encouraging more efficient and environmentally friendly transportation.

Within the U.S., MOD concepts are emerging onto the scene. In May 2016, the Federal Transit Administration (FTA) announced a funding opportunity through its Mobility on Demand Sandbox Program for public transportation projects. FTA’s initiative “envision[s] a multimodal, integrated, automated, accessible, and connected transportation system in which personalized mobility is a key feature.”⁴⁴

Smartphone applications, such as Moovel, formerly GlobeSherpa and RideScout, also serve to link mobility options by providing travel information to users. With three primary smartphone

⁴² Greenfield, Adam. (2014). Helsinki’s ambitious plan to make car ownership pointless in 10 years. The Guardian. Available at: <http://www.theguardian.com/cities/2014/jul/10/helsinki-shared-public-transport-plan-car-ownership-pointless>.

⁴³ Société de Transport de Montréal. (2016) “Integrated Mobility.” Available at: <http://www.stm.info/en/info/fares/special-offers/integrated-mobility>.

⁴⁴ Federal Transit Administration. (2016). “Mobility on Demand (MOD) Sandbox Program.” <https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program.html>.



applications, MoovelTransit, RideTap, and the integrated Moovel, the company enables users to purchase tickets, discover new rides, and plan trips.⁴⁵

Although a more traditional approach to incentivize a shift in commuter trips, telework has gained significant ground in recent years, mainly due to improvements in broadband and communication technologies. Increasingly people can ‘plug-in’ from anywhere (i.e., they no longer need to be at the office to do their jobs). Instead, they can work from home, a coffee shop, or anywhere else through wireless internet connections. Research indicates that half of the American workforce has a job that is conducive to telework, while approximately a quarter of the American workforce teleworks at some frequency.⁴⁶

2.4 Freight Technologies and Logistics

USDOT’s *Beyond Traffic* report estimates that by 2045, freight volume will increase by 45% compared to 2015 values.⁴⁷ In the Atlanta Region, we project a 56% growth in freight volume by the year 2040.⁴⁸ This will put enormous pressure on the transportation network and freight industry to support reliable, efficient goods movement in a sustainable manner. Technology trends affecting freight are coming from two directions:



- 1) Changes in use of technology by companies and consumers, such as 3-D printing and e-commerce, are leading to changes in delivery patterns and customer expectations for rapid delivery of products; and
- 2) Adoption of new technologies such as drones and connected vehicle technologies are enhancing freight logistics and efficiency, enabling new operational concepts such as truck platooning.

2.4.1 E-Commerce and New Service Models

Over the past several years, the commercial and retail industries have made significant leaps in bringing computerization and wireless capabilities into their systems and transferring them to their users. Such improvements have revolved around technologies that allow consumers to engage in commerce activities remotely, without the need to be physically at a store—better known as e-commerce. Freight logistics is under pressure to adapt rapidly to the new services that are arising and the increasing movement towards e-commerce, which enhances the connection between consumers and products.

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. One of the most noticeable

⁴⁵ Moovel, <https://www.moovel.com/en/US>.

⁴⁶ Global Workplace Analytics (January 2016). “Latest Telecommuting Statistics.” Available at: <http://globalworkplaceanalytics.com/telecommuting-statistics>

⁴⁷ U.S. Department of Transportation. (November 2015). “Beyond Traffic: U.S. DOT’s 30 Year Framework for the Future.” Available at <https://www.transportation.gov/BeyondTraffic>.

⁴⁸ Atlanta Regional Freight Plan Update (July 2016). Available at: http://documents.atlantaregional.com/freight/atlanta_regional_freight_mobility_plan_update_2016.pdf



example of the latter is Amazon, which has positioned itself as a leading promoter of e-commerce by providing a wide 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; and
- Amazon's mobile application that enables consumers to buy any available product anytime and anywhere.

In addition, Amazon recently unveiled its first "Prime Air" branded plane, which will be used to provide the company with added shipping capacity as its Prime business grows.⁴⁹ These new services, combined with consumers' increased expectation of faster deliveries, are pushing freight towards more smaller-scale delivery mechanisms, 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.⁵⁰

Within the US, Uber has begun to use its 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.⁵¹ 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.⁵²

Also within the US, car sharing has led to more innovative shipment via the mobile app Roadie which launched in 2015.⁵³ Roadie adds to the car sharing model by linking to the collaborative economy, it does so by connecting people who need to ship items with drivers who have similar origin and destination points as the package. The cost of shippings tends to be cheaper than conventional shipping. Yet, drivers are still able to make enough off of the shipment to the point where the app had 20,000 drivers in the first year. The app also promotes social initiatives by partnering with organizations like goodwill to provide free pickup and delivery of donations.

Although not a new concept (especially internationally), the use of urban distribution centers is

⁴⁹ Frommer, Dan. (August 2016). "This is Amazon's first 'Prime Air' Plane." Recode. Available at <http://www.recode.net/2016/8/5/12382052/amazon-prime-air-plane>.

⁵⁰ John Russel (2015). Uber's Latest Experiment Is Uber Cargo, a Logistics Service in Hong Kong. Available at: <https://techcrunch.com/2015/01/08/uber-cargo/>

⁵¹ 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>

⁵² The Economist (2015). "Uber – Driving hard." June 13 edition.

⁵³ Kristen Hall-Geisrel (2016). Roadie is like Uber for shipping. Available at: <https://techcrunch.com/2016/05/16/roadie-is-like-uber-for-shipping/>



being explored in the U.S. Urban distribution centers enable cooperation among shippers, carriers, and retailers to consolidate deliveries, thus requiring a lower number of delivery trips by trucks between a distribution center and final delivery destinations. These centers may be located at convenience stores and other locations that can take advantage of their already strategic (and accessible) locations for consumers to pick up their orders (from lockers or other secure holding areas) at their convenience within a given timeframe. For example, Georgia Institute of Technology has an Amazon store for package pick up and returns located on campus and open to the public. 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.⁵⁴ 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, such as off-hour delivery (as Barcelona has done since 1998 and New York City has piloted) and requirements for storage space. Combined with the prevalence of online commerce and the emergence of on-demand delivery, these efforts may enhance overall efficiency and help to mitigate increases in traffic congestion. However, they may require changes in loading zones, distribution networks, and urban design. As such, a new vision of freight movement is being implemented in many cities, which are developing 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.⁵⁵

2.4.2 3-D Printing and Changes in Logistics

As Savelsbergh and Van Woensel discuss in their article, “City Logistics: Challenges and Opportunities,” finding efficient and effective ways to transport goods in urban areas is a challenge as urban populations increase, along with related (e-)commerce and the desire for expedient deliveries. The authors advocate for smaller, dynamic delivery in cities, focusing on the use of innovative technologies.

An increase in 3-D printing in manufacturing could have significant impacts on manufacturing, logistics, and customer delivery. Because 3-D printers inherently create a close relationship between design, engineering, marketing and manufacturing, their use holds the potential to shift some manufacturing away from a global supply chain to be closer to the customer base, so companies can more quickly respond to consumer demand. 3-D printing could alter the supply chain by reducing manufacturing lead times substantially, enabling new designs to come to market more quickly, reducing or eliminating the need to carry inventory, and enabling customer demand to be met more quickly.⁵⁶ As is pointed out in an Eno Transportation Policy brief, by

⁵⁴ Greg Bensinger. (2012). “Amazon’s New Secret Weapon: Delivery Lockers.” The Wall Street Journal. Available at: <http://www.wsj.com/articles/SB10000872396390443545504577567763829784538>.

⁵⁵ 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/>

⁵⁶ University of San Francisco, “3D Printing and Its Impact on the Supply Chain.” Accessed at: <http://www.usanfranonline.com/resources/supply-chain-management/3d-printing-and-its-impact-on-the-supply-chain/#.WFwA0FMrlN8>.



enabling manufacturing to occur closer to end users, this may result in reductions in long distance distribution, and further increase patterns that depend on smaller vans rather than larger, heavy-duty trucks.⁵⁷

2.4.3 Connected and Autonomous Freight Vehicles

Fueled by the sector's concern of the level of strain of truck drivers, freight may be one of the first sectors of transportation to deploy AV and CV technologies. 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 advantages as autonomous cars. As one article points out, through "Daimler's 'Highway Pilot,' an autonomous truck has already driven itself on the Autobahn and is slated to enter service in 10 to 15 years."⁵⁸

Furthermore, as part of its CV Pilot Project, Wyoming Department of Transportation 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. This pilot project will support the definition of standards necessary to enhance CV technology for heavy vehicles and promote its deployment in other states. Moreover, CV-enabled platooning software, efficiency-improving automated manual transmissions (which use a computer to shift the manual transmission at the optimal time), and service features like the ability to control a tractor from outside the cab with a tablet for difficult parking scenarios, are coming onto the market.

2.4.4 Delivery through Unmanned Aerial Vehicles (UAVs) / Drones

Drones are likely to have important impacts on package delivery in urban areas. For example, the Swiss company, Swiss Post Ltd, in coordination with California drone manufacturer Matternet, has begun testing the feasibility of using drones for package delivery. Delivery by drones has many applications, including "delivery to peripheral areas" to "transporting emergency supplies."⁵⁹ Additionally, major retailers like Amazon are preparing to begin using drones for delivery purposes. While the technology is available for delivery by drones to occur, concerns over safety and logistics still need resolving, and regulations are under development.⁶⁰

⁵⁷ Akner, William (2014). 3-D Printers: Changing Transportation as We Know It. Eno Center for Transportation. <https://www.enotrans.org/eno-brief/3d-printers-changing-transportation-as-we-know-it>.

⁵⁸ Glass, Dan. (2014). "A Complete Guide to the Future of U.S. Freight Movement." The Atlantic CITYLAB. Available at: <http://www.citylab.com/work/2014/10/a-complete-guide-to-the-future-of-us-freight-movement/381012/>.

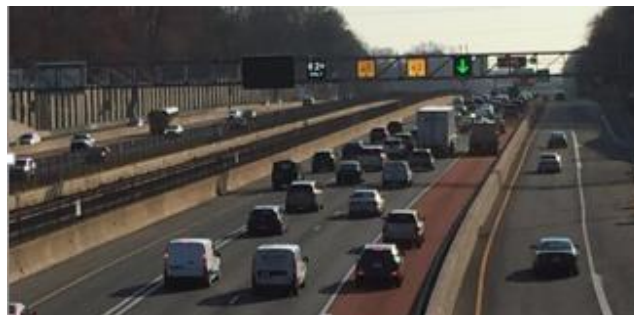
⁵⁹ Whelan, Robbie (2014 July). Are Drones the Future of Air Freight? Available at: <http://www.wsj.com/articles/are-drones-the-future-of-air-freight-1436468089>.

⁶⁰ Morgan, David (2015 June). FAA Expects to Clear U.S. Commercial Drones Within a Year. Available at: <http://www.reuters.com/article/2015/06/17/us-usa-drones-congress-idUSKBN0OX1P020150617>.



2.5 Transportation System Management & Operations and Smart Infrastructure

In addition to changing how drivers interact with their vehicles and each other, technology also enables transportation agencies to enhance the way in which they operate and manage transportation systems. In particular, access to real-time traveler data is playing a growing role in traveler information, transportation system operations, and travel demand management.



2.5.1 Traveler Information and Incentives

Comprehensive 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 companies, like Waze/Google, serve as an additional resource for travelers.

State departments of transportation (DOTs) and local governments are now turning to the private sector to acquire 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. Early adopters to this were Boston, MA; Los Angeles County, CA; Utah, Florida, and the New York Police Department. Through its Connected Citizens Program, Waze is able to “exchange publicly available incident and road closure reports,” helping government partners more quickly and efficiently respond to accidents and congestion. In return, partners provide Waze with in-house data that is aggregated and incorporated into the Waze platform. As of June 2016, the Connected Citizens Program had 45 North American partners, which includes state and local government agencies and software providers. Partners from the Atlanta Region include the City of Atlanta, City of Johns Creek, and the Georgia Department of Transportation. In addition to the 45 North American partners, the program has 25 international partners.⁶¹

Public Transit

Transit agencies are using advances in technology: 1) to streamline and improve fare collection, scheduling, and routing of transit services through enhanced Intelligent Transportation Systems (ITS); and 2) to adopt social media to achieve a two-way interaction between agency and users, increasing transparency and accountability, while improving how they monitor transit service.⁶² The end-result of this is a system that enables a transit agency to track all of its assets in real time, with an accurate approximation of how many people are riding them at a particular time. A well-informed user is also able to obtain and provide information from/through several alternatives (e.g., Twitter, Facebook, Instagram and other social media platforms). With this vast dataset of historical and real-time information, transit officials can efficiently allocate their resources based on reliable forecasts and can better control their operation as well (e.g., when

⁶¹ Connected Citizens Program (June 2016). Waze. Available at:
https://wiki.waze.com/wiki/Connected_Citizens_Program.

⁶² Newcombe (2015). “3 Advances in Transit Technology.” <http://www.govtech.com/dc/articles/3-Advances-in-Transit-Technology.html>



and where to stop).

Partnering with Mobile Apps to Actively Influence Demand with Incentives

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. Impacts on travel behavior may be associated with the way in which mobile apps affect how travelers conceptualize and respond to transportation pricing, how information availability affects their behavior, social pressure and reframing of norms about travel choices, and delivery of incentives, among other factors.⁶³

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.⁶⁴ Another start-up in this field is Metropia, which aims to link incentives with local businesses for time and route shifts.⁶⁵ 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.⁶⁶ 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.⁶⁷

The USDOT’s Applications for the Environment: Real-Time Information Synthesis (AERIS) Program has performed significant modeling and research on ways technologies and incentives could support the environment. The research program developed five operational scenarios (Eco-Signal Operations, Eco-Lanes, Low Emissions Zones, Eco-Traveler Information, and Eco-Integrated Corridor Management), that would provide environmental benefits.⁶⁸

2.5.2 Payment Methods

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. Travelers can worry less about payment types taken as more companies begin to accept credit

⁶³ Federal Highway Administration (2016). “Smartphone Applications to Influence Travel Choices: Practices and Policies.” U.S. Department of Transportation. Prepared by Shaheen, Cohen, Zohdy, Ismail, and Kock. Available at: <http://www.ops.fhwa.dot.gov/publications/fhwahop16023/fhwahop16023.pdf>.

⁶⁴ Urban Engines. <https://www.urbanengines.com/about/>.

⁶⁵ Metropia. <http://www.metropia.com/solutions>.

⁶⁶ Mobidot. <http://www.mobidot.nl/en/index.php>.

⁶⁷ 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>

⁶⁸ Applications for the Environment: Real-Time Information Synthesis (AERIS) Program. United States Department of Transportation. www.its.dot.gov/aeris/pdf/AERIS_Operational_Scenarios011014.pdf.



cards for payment. At its full potential, transit passengers will be able to worry less too, as they will no longer need to keep track of multiple fare passes, one for each mode.

Transportation network companies 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. Locally, MARTA has piloted a similar mobile app which is planned to be released to the public mid 2017. This eliminates the need for a paper ticket and enables users to avoid the inconvenience and frustration of purchasing tickets at a kiosk or carrying exact change for bus fare.⁶⁹

2.5.3 Integrated Corridor Management and Active Transportation and Demand Management

Transportation agencies also are using technology to better manage and operate transportation systems as coordinated networks. The concept of Integrated Corridor Management (ICM) 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.⁷⁰

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).⁷¹

Active Traffic Management

Defined by the Federal Highway Administration (FHWA) as “the ability to dynamically manage recurrent and non-recurrent congestion based on prevailing and predicted traffic conditions,” active traffic management improves system efficiency and safety through the use of integrated systems with new technology.⁷² Strategies for active traffic management include: adaptive ramp metering, adaptive traffic signal control, dynamic junction control, dynamic lane reversal or counterflow lane reversal, dynamic lane use control, dynamic merge control, dynamic shoulder lanes, dynamic speed limits, queue warning, and transit signal priority.

One example of active traffic management is Minnesota's Smart Lanes project. These Smart

⁶⁹ TriMet. <http://trimet.org/app/index.htm>

⁷⁰ ITS Joint Program Office, Integrated Corridor Management, available at: <http://www.its.dot.gov/icms/index.htm>

⁷¹ FHWA, ATDM Program, available at: <http://www.ops.fhwa.dot.gov/atdm/about/overview.htm>

⁷² FHWA, Active Traffic Management, available at <http://www.ops.fhwa.dot.gov/atdm/approaches/atm.htm>.



Lanes have electronic signs over highway lanes that provide real-time information to help motorists make informed commute decisions. The signs show information on road conditions, which helps improve traffic flow and safety while simultaneously reducing congestion.⁷³

Active Demand Management

Active demand management utilizes data and technology to dynamically manage demand by redistributing travel to less congested times of day or routes, or across modes, such as transit and ridesharing. This goal can be achieved through several avenues, including dynamic fare reduction, dynamic high-occupancy vehicle (HOV)/managed lanes, dynamic pricing, dynamic ridesharing, dynamic routing, dynamic transit capacity assignment, on-demand transit, predictive traveler information, transfer connection protection (ensuring that bus connections do not depart before the arrival of connecting buses), and incentives.⁷⁴

Several examples of active demand management exist throughout the country. Interstate 580 in the Bay Area uses dynamic pricing to encourage carpooling. I-580 Express lanes are free of charge for carpools, vanpools, motorcycles, buses, and clean air vehicles, but single occupancy vehicles are required to pay a toll between the hours of 5am and 8pm Monday through Friday.⁷⁵ By making solo drivers pay, while everyone else can use the express lanes for free, use of shared and alternative travel modes is incentivized.

Active Parking Management

Defined by FHWA as the dynamic management of parking facilities in order to optimize performance and utilization of parking facilities, active parking management has the potential to affect travel demand by influencing trip timing choices, mode choice, and parking facility choice. Strategies for active parking management include dynamic overflow transit parking, dynamic parking reservation, dynamic wayfinding, and dynamically priced parking. These strategies are being applied and tested in urban areas in California, as well as New York and Washington State, among others.⁷⁶ In New York City, for example, the city is piloting the PARK Smart program, which is intended to increase availability of on-street parking through increased vehicle turnover, increased safety, reduced double-parking, reduced pollution, and reduced congestion from circling vehicles. The program uses dynamically priced parking to reduce demand and discourage drivers from staying in a metered space longer than necessary.⁷⁷

2.5.4 Smarter Infrastructure

Technology can also be used within transportation infrastructure to monitor the condition of bridges and pavements (along with use of mobile technologies, such as drones, to reduce the cost of bridge inspections). While asset management is not the focus of this study, several infrastructure related developments have potential impacts on mobility, safety, and the environment. For example, a transit property in South Korea is looking at wireless technology

⁷³ Minnesota Department of Transportation, Smart Lanes. Available at <http://www.dot.state.mn.us/smartlanes/>.

⁷⁴ FHWA, Active Demand Management.

⁷⁵ Alameda County Transportation Commission. Bay Area Express Lanes. Available at <http://www.alamedactc.org/580express>.

⁷⁶ FHWA, Active Parking Management. Available at <http://www.ops.fhwa.dot.gov/atdm/approaches/apm.htm>.

⁷⁷ New York City Department of Transportation. PARK Smart. Available at <http://www.nyc.gov/html/dot/html/motorist/parksmart.shtml>.



that can provide embedded charging capabilities along transit routes⁷⁸.

New technology for Smarter Highways development in Netherlands includes dynamic paints and glowing lines that charge at daytime, and glow at night for eight hours⁷⁹. 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.⁸⁰ The District of Columbia recently installed a new kinetic sidewalk in an urban park. The sidewalk uses pavers that convert energy from pedestrians' footsteps into electricity, which is stored in batteries and used to power LED accent lights in the park at night.⁸¹ Georgia DOT partnered with company The Ray to install 18 miles of solar roads on Interstate 85 in late 2016, making it the first stretch of solar road in the nation.⁸²

2.6 The Concept of Smart Cities

While the future is uncertain, all five of the overarching technology trends identified are occurring and are likely to continue to advance. This confluence of technologies is often discussed in the context of “smart cities”, in which transportation is increasingly *instrumented*, *interconnected*, and *intelligent* (see Figure 2-2).

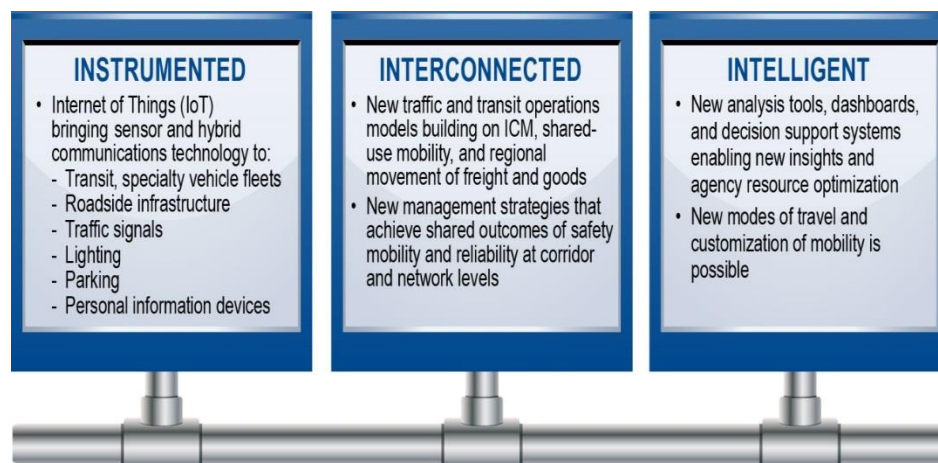


Figure 2-2. Aspects of Future Transportation Networks.

Beyond transportation, cities (and urbanized areas broadly) have become smarter and more connected via technology, and advancements in the IoT promises potential for a truly smart city. A smart city is defined as “a system of interconnected systems, including employment, health care, retail/entertainment, public services, residences, energy distribution, and not least,

⁷⁸ Barry, Keith. “In South Korea, Wireless Charging Powers Electric Buses” Article in Forbes, August 2015 <http://www.wired.com/2013/08/induction-charged-buses/>.

⁷⁹ Smarter Highways, <https://www.studiooosegaard.net/project/smart-highway/info/>

⁸⁰ Missouri DOT, Road to Tomorrow, <http://www.modot.org/road2tomorrow/>

⁸¹ DCist, “Electricity-Generating Sidewalk Unveiled in Dupont.” Accessed at: http://dcist.com/2016/11/new_electricity-generating_sidewalk.php.

⁸² Southeast Green, “The Ray Unveils Two New Transportation Technologies – Both “Firsts” in the U.S.” Available at: <http://www.southeastgreen.com/index.php/news/georgia/16633-ga-solar-road>



transportation...tied together by ICT that transmit and process data about all sorts of activities within the city".⁸³ Smart cities can use their technological infrastructure in conjunction with mobile applications to support transportation system operations and maintenance. The City of Boston has capitalized on smart technology, using a mobile application, StreetBump, to determine pothole locations and uses sensors mounted on the roofs of buildings to monitor greenhouse gas emissions.⁸⁴

Because of strong interest in smart cities, the USDOT announced the Smart City Challenge in 2015, pledging up to \$40 million to a mid-sized city to help define the Smart City and integrate innovative technologies into the local transportation system. The challenge encouraged 78 cities to submit applications, seven of whom were selected as finalists. Those finalists developed detailed vision statements, describing their plans for becoming a Smart City. In June 2016, USDOT announced Columbus, Ohio as the winner of the Smart City Challenge, awarding the city \$40 million in funding, as well as an additional \$10 million from Vulcan Inc.

The seven vision statements of the finalists are summarized briefly below. While each vision statement is unique to the different cities, all of the visions rely heavily on the use of data and CV technology, with a focus on using technology to enhance accessibility, safety, and equity.

Austin: Austin's Vision for a 21st Century Mobility laid out a plan to "make Austin, Texas the innovation epicenter for introducing, testing, evaluating, refining, commercializing, and scaling a 21st Century Mobility System." At the center of Austin's vision is Austin's Mobility Innovation Center (MIC). With the MIC serving as the center of the Smart City network, Austin envisioned five broad initiatives that it would implement to push it into the future: 1) AV and CV, 2) Electric Fleets, 3) Sensor Systems, 4) Travel Access Hubs, and 5) Packaged Mobility Service.

Columbus: Columbus envisioned a city with 1) access to jobs, 2) smart logistics, 3) connected citizens, 4) connected visitors, and 5) sustainable transportation. To achieve this vision, the city will develop smart corridors, enhance the timeliness and quality of traffic condition data, push real information to users on traffic and parking conditions and transit options, develop and deploy communication technology solutions for lower income residents, and expand the use of electric and smart vehicles. Key to implementing Columbus' vision are strong partnerships with local and regional stakeholders as well as with international counterparts.

Denver: Denver's Smart City Program Mission was to "Provide the bridge between the people, services, goods, travel choices, information, and technology, allowing for engagement, accessibility, adoptability, and adaptability while being flexible enough to continually evolve, learn, and get 'smarter.'" The city's vision had three primary components:

- MOD Enterprise, which intends to reduce barriers to access through the use of smartphone applications and interactive kiosks powered by the city's 2 million lineal feet of fiber;
- Transportation Electrification, which will help expand the electric vehicle market in the area;
- Intelligent Vehicles, which intends to expand the state's CV program and develop an

⁸³ Federal Highway Administration. The Smart/Connected City and Its Implications for Connected Transportation. Available at: http://www.its.dot.gov/itspac/Dec2014/Smart_Connected_City_FINAL_111314.pdf.

⁸⁴ Federal Highway Administration. The Smart/Connected City and Its Implications for Connected Transportation.



environment conducive to AVs.

In addition, Denver would create an Enterprise Data Management (EDM) Platform to support the three primary components of the vision and serve as a centralized data platform.

Kansas City: Kansas City's Smart City Vision was comprised of three broad pillars: 1) Deploying East Side Transportation and Connectivity Solutions, 2) Increasing Key Corridor Safety through CV and AVs, and 3) Increased Mobility and Accessibility through Information Sharing. Through these pillars, Kansas City would combine new technology with existing transportation infrastructure in order to create an updated transportation system that would provide benefits both for the city as a whole and its residents.

Pittsburgh: The City of Pittsburgh's vision for the Smart City was centered on the "confluence of transportation and energy," and would be achieved through an "open platform and corresponding governance structure to improve safety, equity, and efficiency of the transportation network..." Pittsburgh intended to create a platform for a new economy that is "rooted both in the foundation and growing interrelation of information communications technology, intelligent transportation systems, and energy and utility networks," termed SmartPGH and governed by the SmartPGH Consortium. Within SmartPGH, the city would embark on several initiatives to achieve its goals. These initiatives included: 1) the deployment of the Surtrac real-time adaptive signal control system, with smart transit priority; 2) the implementation of intelligent freight management; 3) the creation of an autonomous shuttle network; 4) the development of a clean energy transportation corridor and introduction of new city fleet EVs; 5) the creation of MovePGH, a multimodal travel and accident reporting application; and 6) the extension of already tested dynamic pricing parking along specific corridors.

Portland: Portland's vision for USDOT's Smart City Challenge presented UB Mobile PDX, a technology platform that "leverages current technologies to provide common access for a spectrum of users." UB Mobile PDX intends to provide users with connections to Portland's transportation landscape and will help enable frictionless movement throughout the city. The platform included: 1) a marketplace, user interface, and open data cloud; 2) a technology hardware foundation; and 3) real-world implementation projects.

San Francisco: San Francisco's vision for a Smart City focused on reducing citizen's reliance on single occupancy vehicle (SOV) trips and increasing the prevalence of connected and automated vehicles. To achieve these goals, the city planned to implement several pilot programs across the city. Elements of San Francisco's vision include developing an integrated mobility smartphone application, increasing access to carshare, bikeshare, and EV infrastructure in all neighborhoods, and installing wireless networks in neighborhoods.

2.7 Combined Trajectory of Trends / Future Scenarios

Beyond the concept of Smart Cities, it is important to recognize that the future may play out in different ways, and there is considerable uncertainty about how technologies will be adopted and which trends will be most influential. A recent white paper by McKinsey & Company and Bloomberg, titled "An Integrated Perspective on the Future of Mobility" notes that the way people move around the urban environment is primed for dramatic change over the next 10 to



20 years, and highlighted the importance of looking at trends together.⁸⁵ The paper envisions three mobility trajectories, with trends such as sharing, autonomous driving, and electrification moving forward at a different pace:

- 1) **Clean and Shared:** Particularly in densely populated metro areas in developing countries, where widespread use of self-driving vehicles may not be an option in the short- or medium-term (due to poor infrastructure, interference from pedestrians, and lack of adherence to traffic regulations), there may be a shift to cleaner transport in the form of EVs, while optimizing shared mobility and expanding public transit.
- 2) **Private Autonomy:** In more sprawling regions where having a car is all but essential, new vehicle technologies such as self-driving and EVs may take off, combined with new strategies such as demand-driven congestion charges.
- 3) **Seamless Mobility:** In the most densely populated, high-income regions, boundaries among private, shared, and public transport will be blurred, with MOD delivered through a high-quality public transit system supported by self-driving shared vehicles.

The trends identified in this research further support this idea of looking at the confluence of separate trends. The technology foundations of big data, connectivity, and the IoT have provided support for CVs, new forms of MOD, and advances in transportation system management. Several of the trends are likely to come together in ways that reinforce each other. Automation and electrification of the vehicle fleet are mutually supportive, as AVs are much easier to recharge with electricity than to refuel with conventional fossil fuels. Use of smartphones and accessible real-time data has supported new carsharing and ride-hailing services, and offer potential for MOD services that tie together all modes with mobile payment methods. Consequently, it is likely that in the future, autonomous EVs will be utilized for MOD services while potentially being used to support urban goods distribution as well.

While this typology is not used to predict how trends will play out in the Atlanta area, it can be used to recognize the importance of looking both at the impacts of individual technology trends and perhaps most importantly at the combined impacts of trends, as a basis for considering potential regional policy implications or needs. The Atlanta Regional Commission has been developing and testing similar scenarios via the SHRP2 grant.⁸⁶

⁸⁵ See: <https://about.bnef.com/white-papers/integrated-perspective-future-mobility/>

⁸⁶ Atlanta Regional Commission. "Winning the Future: Sharpening our Focus". 2016. Presentation. Available at: http://documents.atlantaregional.com/tcc/2016/2016-10-07/SHRP2_Visioning.pdf



3 ASSESSMENT OF TECHNOLOGY TRENDS

Looked at independently, each of the technology trends discussed in the previous section is significant. Combined, the implications may prove to be dramatic. Consequently, while it is useful to examine the impacts of individual trends, ***it is essential to consider the combined impacts of the technology trends that are simultaneously advancing.***

3.1 Societal, Private Sector, and Public Sector Impacts of Technologies

The effects of technology trends identified in this report have many potentially important implications on society, the private sector, and the public sector. Moreover, the simultaneous advances in these trends and convergence of many technology advances could lead to significant changes in mobility in the future, including not only changes in the way in which people interact with their vehicles but also whether they own private vehicles at all.

The impacts of technologies likely could lead to further cascading impacts. For instance, the safety and mobility impacts of CVs and AVs have potential to create significant changes in travel behavior. By facilitating personal independence and mobility, while enhancing safety, and making travel time more productive (for reading, working, relaxing, etc.), advanced technology vehicles could significantly increase the demand for automobile travel. This could lead to increased urban sprawl as well as increased traffic.

At the same time, many experts note potential for creating truly sustainable, accessible mobility. For instance, AVs could be transformational in challenging the very idea of car ownership. Motor vehicles are among the most expensive products most people own, but sit idle for over 95 percent of the time. While the high costs have been justified by the convenience of the mobility provided by personal vehicles, new shared mobility options and AVs would provide greater accessibility. Use of EVs with solar or wireless charging could significantly reduce the emissions from vehicles. These changes have the potential to transform urban form in sustainable ways—for instance, removing the need for on-street parking and enabling more opportunities for bicycling facilities and greenspace. Off-street parking needs would be reduced as well as vehicles would not be sitting idle in parking for significant portions of the day. Rather than detract from transit, shared mobility options could enhance fixed route transit services by providing sustainable first-mile, last mile connections.

The direction of many of these trend implications is uncertain, but some general observations are provided in Table 3-1.

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: Overview of Trends and Policy Implications



Table 3-1. Potential Overarching Implications of the Identified Transportation Technology Trends.

Societal Implications	
• Advances in roadway safety, with fewer fatalities and injuries, associated with automation	
• Increased accessibility for those with disabilities (e.g., blind, mobility impaired), with lack of access to vehicle ownership, or who choose not to own a vehicle	
• Reduction in vehicle ownership and shift toward a mobility “service” model	
• Impacts on vehicle travel and urban form, with corresponding impacts on accessibility to jobs for disadvantaged populations	
• Sustainability benefits from reduction in use of fossil fuels, including air quality improvements and greenhouse gas reduction due to electrification, vehicle platooning, and enhanced traffic operations	
• Significant reduction in employment of “drivers”, such as in trucking, taxi services, and transit	
Private Sector Implications	
• Reduced freight and shipping costs as fleets become electric and automated	
• Higher expectations from consumers for faster delivery of goods	
• Changes to business models at automobile companies if private vehicle ownership drops	
• Changes to industries that rely on vehicle drivers if automated vehicles become more prevalent or the norm	
• Changes to business models between automobile companies and technology companies as vehicles and technologies merge	
• Changes to business models at freight companies with the advent of 3-D printing and automated delivery mechanisms (vehicles and drones)	
• Land use market changes, as parking needs, warehouse needs, and building design may change	
Public Sector Implications	
• Increased availability of real-time and accurate data leading to better predictability, modeling, planning, and management of the transportation system	
• Necessity in development guidelines, standards, and policies related to pilot testing new technologies, accepting and adopting new technologies, and ensuring the safety and responsibility of new technologies	
• Changes to infrastructure <ul style="list-style-type: none"> ○ Option 1 - Increased installation of sensors and actuators on existing infrastructure to improve connectivity and the collection of Big Data ○ Option 2 - Limited need for technology infrastructure on the roadways and a dependence on the AI from CV/AVs 	
• Increased focus on data analyst, cybersecurity, and system engineer personnel over engineers at transportation agencies	
• Changes to transportation agencies’ business models as “Mobility on Demand” becomes an accepted and pursued concept (i.e., different modes are not managed by separate agencies, but one overall agency that is managing passenger throughput vs mode-specific throughput).	
• Zoning requirement changes as vehicle ownership patterns change (e.g., requirements for housing units or commercial properties to have X number of spaces is reduced)	



3.2 Assessment Framework and Analysis Methodology

In order to provide a useful assessment of the impacts of transportation technology in ways that would support policy and planning decisions that help to shape future preferred outcomes, the research team developed an assessment framework to more fully analyze and explore these implications. The team's approach consisted of three steps:

- 1) First, the project team explored regional goals articulated by the Atlanta Regional Commission (ARC) to identify *key issues and impacts of importance to the region*. Based on the goals in the region's policy framework,⁸⁷ regional transportation plan,⁸⁸ SHRP2 visioning process,⁸⁹ and input from the Technical Advisory Group, the project team identified impacts in the categories of travel, society, employment, and infrastructure, decomposed into fifteen (15) distinct elements. Table 3-2 details these elements.

Table 3-2. Impacts and Specific Elements Assessed in Framework

Impact Field	Element	Description of Impact
Travel	Vehicle Ownership	Reduce the number of vehicles owned per household and overall need for private vehicles
	Travel Choices	Increase mode choices, including support for transit, shared rides, bicycling, and walking
	Vehicle Travel Demand	Reduce the level of vehicle miles traveled
	Traffic Congestion	Reduce average travel time and delay
	Reliability	Improve travel time reliability
	Travel Costs	Reduce the share of household income used for transportation
Societal	Land Use	Strengthen walkable and vibrant centers
	Safety	Reduce fatalities and injuries
	Environmental Quality	Improve air quality, reduce greenhouse gas (GHG) emissions
	Equity	Improve accessibility for the disabled, elderly, low income, veterans, and/or other disadvantaged populations
Employment	Direct Employment	Increase middle income employment in the region
	Economic Development	Create opportunities to be a hub of innovation
Infrastructure	Monitoring Conditions	Reduce costs associated with monitoring system conditions and maintenance
	Upgrade / New	Reduce costs associated with new/upgraded

⁸⁷ Atlanta Regional Commission. (2016). "Policy Framework." <http://documents.atlantaregional.com/The-Atlanta-Region-s-Plan/policy-framework.pdf>

⁸⁸ Atlanta Regional Commission. (2016) "Regional Transportation Plan." <http://atlantaregionsplan.com/regional-transportation-plan/>

⁸⁹ a) Atlanta Regional Commission. (October 2016). "Sharpening our Focus: Transportation and Air Quality Committee." <http://documents.atlantaregional.com/taqc/2016/2016-10-13/SHRP%202.pdf>; b) Atlanta Regional Commission. (September 2016). "Sharpening our Focus: Transportation and Air Quality Committee." http://documents.atlantaregional.com/taqc/2016/2016-09-15/09-15-16_SHRP2_Visioning.pdf; and c) Atlanta Regional Commission. (November 2016). "Sharpening our Focus: Transportation and Air Quality Committee." http://documents.atlantaregional.com/taqc/2016/2016-02-11/2016_WorkProgram_SHRP2.pdf



Impact Field	Element	Description of Impact
		infrastructure
	Transportation Funding	Ensure sufficient funding for infrastructure development and maintenance

Additionally, there are other impacts of importance to the region, such as *improving public health*. This outcome, however, can occur through more active living, reduced fatalities and injuries, and improved air quality, which are addressed as individual elements.

- 2) Next, the project team scored each of the key technologies in relation to these impacts. We explored two dimensions for each impact:
 - a. *Direction (and magnitude) of effect* – The direction of the impact is important to understand in order to assess which trends may contribute to positive outcomes, negative outcomes, and where outcomes might vary (be either positive or negative), or likely have no or little effect. Technology trends with potentially negative outcomes may be a cause for concern and a focus area for policy intervention.
 - b. *Certainty of expected impact* – Another dimension of importance relates to how certain the impact is: highly certain, somewhat certain, or uncertain. The certainty of the impact is partly determined by whether the impact is a direct result of the technology or an indirect result, influenced by external factors.

These two dimensions were scored quantitatively and examined qualitatively, recognizing the interplay between these two dimensions (See Appendix B). CV and AV technologies are designed with the *direct* purpose of enhancing safety, so the effect of the technologies is anticipated to be significantly *positive, with a high level of certainty*. In contrast, these technologies are likely to increase travel demand by making it less burdensome to drive, but the impacts are somewhat *uncertain*, as this is an *indirect* outcome of the technology.

- 3) Finally, the project team aggregated the results across all of the expected technology trends. Looking at the regional goals and outcomes, it is clear that some technology trends have implications in different directions, suggesting an overall higher level of uncertainty associated with the effects of the combined set of trends.

3.3 Assessment Findings

Figure 3-1 maps the results from the analysis, with the horizontal axis representing the direction and magnitude of impact (positive or negative), and the vertical axis representing the level of certainty of the impact. Impacts are located on the map based on judgement of expected impacts over the long-term (more than a 15-year period). Several impacts may be positive and/or negative, and these are represented with a horizontal bar spanning a range across the axis.

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: Overview of Trends and Policy Implications

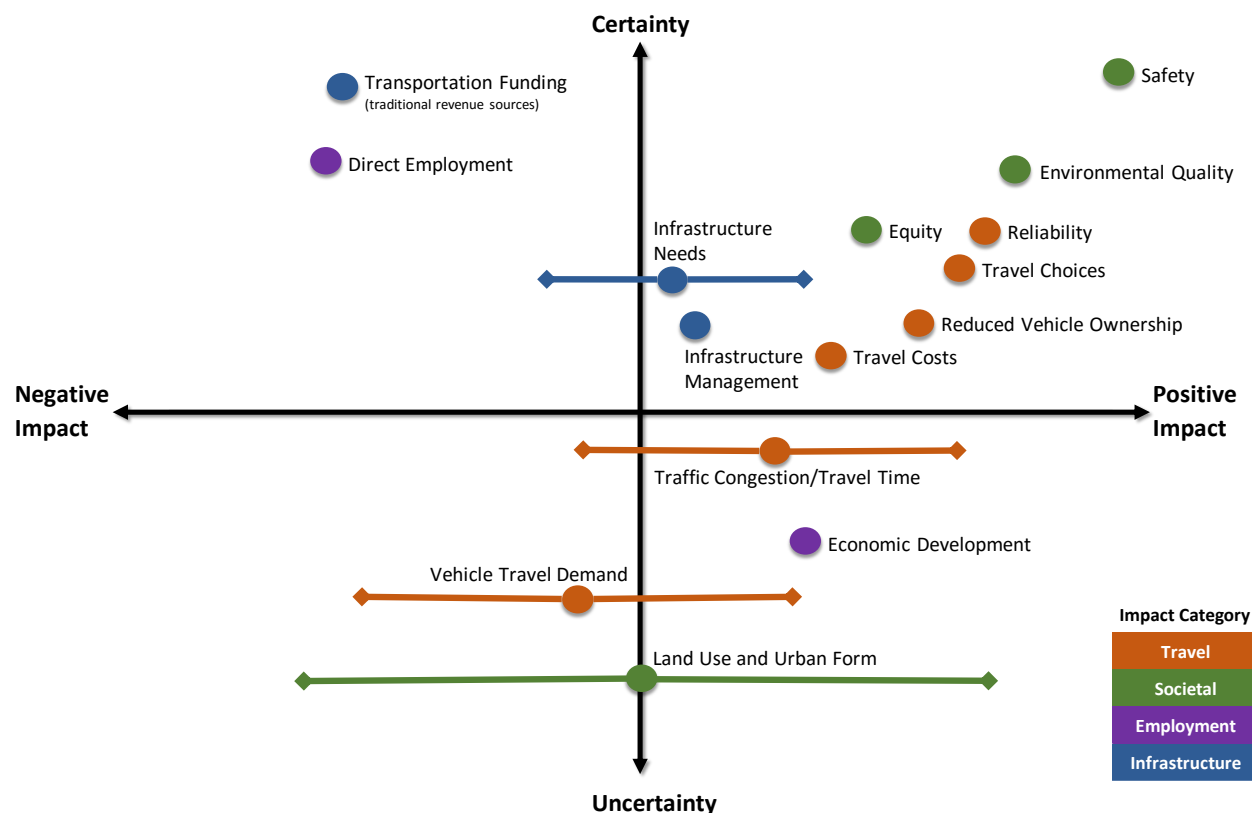


Figure 3-1. Implications of Transportation Technology Trends across Two Dimensions

The analysis mapping of the combined set of technology trends highlights the following:

- Safety and environmental quality are anticipated to improve significantly, with a relatively high level of certainty.**
 - CV and AV technologies are being developed and designed as safety enhancements. Outfitted with sensors, and with features such as lane departure warning and active crash avoidance, CVs are being developed to significantly reduce crashes. AVs remove driver error and distraction, and offer the potential for even more dramatic improvements in safety.
 - EV technologies will reduce fossil fuel use, air pollutant emissions, and GHG emissions (even if vehicle travel increases).
- Travel-related impacts are quite varied and some of these impacts are difficult to assess with certainty.** Technology trends are expected to *increase travel choices* through new shared mobility options, including ride-hailing services, dynamic ridesharing, carsharing, bicycle sharing, and other options, as well as providing access to “on demand” mobility options. Overall, with AVs and shared mobility options, it is anticipated that both *vehicle ownership and single occupancy vehicle (SOV) use will decline* as it becomes easier for individuals to call up a car as needed and avoid the costs associated with owning a vehicle. *Travel time reliability is anticipated to improve* due to better data on real-time travel conditions and fewer incidents. However, *impacts on vehicle travel demand are uncertain*. While e-commerce, shared mobility options, and



reduced vehicle ownership may reduce vehicle travel demand, AVs make it less burdensome to have lengthy driving trips, and might lead to increased VMT. Overall, advanced technology vehicles will need less space between vehicles, which may increase the effective capacity of existing infrastructure and *may reduce congestion*, but this again depends on the level of change in VMT.

- **Technology trends are likely to lead to *job losses in some industries*, but the *potential exists for new jobs in growing advanced technology industries and in relation to some new service models*.** Some technologies and trends, such as AVs and changes in logistics, will result in *direct job losses in "driving" fields* (bus drivers, taxi drivers, truck drivers, etc.). However, manufacturing, logistics, hardware/software maintenance, and data analytics offer potential for new jobs associated with the emerging technologies. The economic development potential, however, for the Atlanta region is somewhat uncertain.
- **Technology trends are likely to reduce transportation infrastructure expansion needs (and associated costs), but are also likely to create some new costs, and cause a reduction in funding sources.** For instance, CVs and AVs may reduce the need for additional highway capacity by enabling more vehicles to operate at closer distances within the existing roadway footprint; moreover, improved routing may help to optimize overall system usage. At the same time, at least in the next several years, investments in smart, instrumented "smart" or connected infrastructure may entail additional costs to install and maintain. Infrastructure wear and tear and maintenance costs are likely to be reduced through smarter infrastructure and use of technologies such as drones for monitoring bridge and pavement conditions. As EVs are more widely adopted and dependence on oil is reduced, State DOTs will see a reduction in revenues from current funding sources, such as state gas taxes.
- **Land use impacts are the most uncertain, with potentially divergent trends toward either increasing sprawl or leading to development patterns that are more efficient.** On the one hand, by reducing the burden of driving, AVs could encourage longer commutes. Combined with expanding e-commerce, drone deliveries, and other changes in logistics, these trends *could lead to growth in lower-density, exurban areas*. On the other hand, more seamless on-demand mobility is likely to dramatically reduce vehicle ownership in urban areas, thereby reducing parking demand and enabling the reuse of parking spaces for green space, bicycling and walking infrastructure, and affordable housing, helping to *support urban centers*.

Appendix B provides a qualitative summary of the assessment of each individual technology. It demonstrates that the largest uncertainties and possible negative impacts are associated with AV technology. When compared to other technologies, AVs are likely to have some of the most dramatic impacts on vehicle ownership and transportation system performance, and will affect both passenger and freight transportation.

3.4 Timeframes of Expected Impacts

Although the timeframes of technology implementation and their resulting impacts are subject to significant uncertainties, it is also useful to consider the potential impacts over a temporal scale. For several of the impacts, Figure 3-2 provides a simplified assessment of likely level of impacts



along the spectrum of near-term (within 5 years), mid-term (5 to 15 years), and long term (over 15 years).

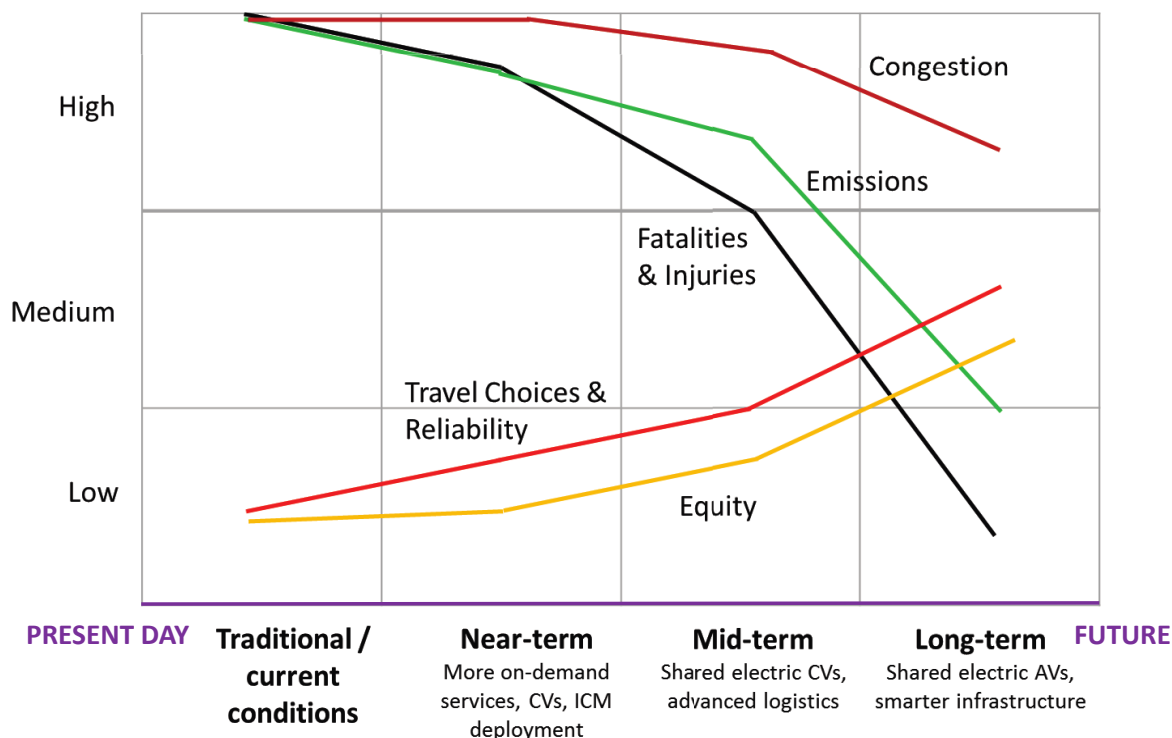


Figure 3-2. Estimated Timeframes for Outcomes

This temporal assessment shows that some of the most dramatic effects will likely require multiple technology advancements over a period of time. For instance, while connected vehicle technologies are anticipated to improve safety in the near-term, there are near-term challenges associated with a combination of advanced technology and conventional vehicles operating in mixed traffic, as well as interactions between vehicles, pedestrians, and bicyclists; consequently, the most dramatic effects will occur over time with larger scale shifts of the vehicle fleet toward AVs.

Some of the most important factors that might affect the pace of change and the trajectory of impacts include:

- **Artificial Intelligence (AI) and Machine Learning:** On controlled access highways, automation has significant potential for application. In an urban environment of complexity (pedestrians, bicyclists, loading zones, etc.) however, computers are challenged to make effectively all of the decisions needed. The level of advancement in AI is a question in the time frame for widespread AV adoption.
- **Cyber-security:** Security and cyber risk also are important issues with automation and connectivity, which could hinder adoption.
- **Urbanization and land use patterns:** Shared use mobility options and urban freight delivery enhancements are most efficient in urbanized areas where the population density is great enough to enable sharing of vehicles and other multimodal options.



3.5 Implications for Policy Development

Looking at the placement of expected technology impacts in Figure 3-1, proactive policy interventions may help move impacts toward the upper right-hand corner of the four-quadrant diagram. Given the potential negative impacts and uncertainties associated with impacts on vehicle travel demand and land use, this diagram is helpful in recognizing the potentially important need for policies, programs, and pilot efforts to support positive outcomes in these areas. An example might be pilot initiatives to help ensure that AVs are deployed to support first-mile/last-mile access to transit, or incentives and policies to increase use of high-occupancy shared mobility options. Similarly, while there are potential positive economic development implications of new transportation technologies, the impacts in the Atlanta region are uncertain, and could benefit from a concerted initiative to foster the region as a hub of innovation for emerging technologies.

Beyond those outcomes falling outside of the upper right-hand quadrant, it is useful to recognize that even in the cases where some effects are likely to be positive, there may be unintended consequences or specific issues of concern. While AVs and increased Mobility on Demand (MOD) services are expected to improve equity by increasing accessibility for the disabled, the elderly, and those without a private vehicle, it will be important to consider issues, such as barriers to technology access. For instance, lower-income unbanked households (those without credit cards or bank accounts) may experience barriers to participation in new on-demand mobility options that rely upon mobile apps. There is also a possibility that with shifts toward shared use and private sector services, in which private individuals or companies can choose if they serve customers, there could be increased barriers associated with racial or other forms of discrimination. However, over time, as MOD services shift toward automation, these effects may be lessened or avoided.

The mapping of technology impacts in Figure 3-1 provides a useful context for examining policies to help shape positive outcomes. Based on this, Figure 3-3 provides a framework for exploring the impacts of technology trends on societal outcomes and policy needs. It highlights that:

- Some effects of the technology trends are *direct*, while others are *indirect*. The direct impacts generally have a higher level of certainty, while indirect effects have more uncertainty and often more risk for potentially negative implications.
- Transportation policies can be *responsive* to changes created by technology or may be *proactive* to help to shape those outcomes. Examples of responsive policies include changes in vehicle licensing requirements to respond to AV technology, shifts from programs focused on road safety enforcement (e.g., speeding, drunk driving, distracted driving) to cybersecurity, and changes in transportation infrastructure funding mechanisms in response to a reduction in traditional fuel tax revenue sources. Proactive policies are those that focus on actively promoting positive outcomes, such as encouraging more rapid adoption of low emissions vehicles and connections to public transit.

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: Overview of Trends and Policy Implications

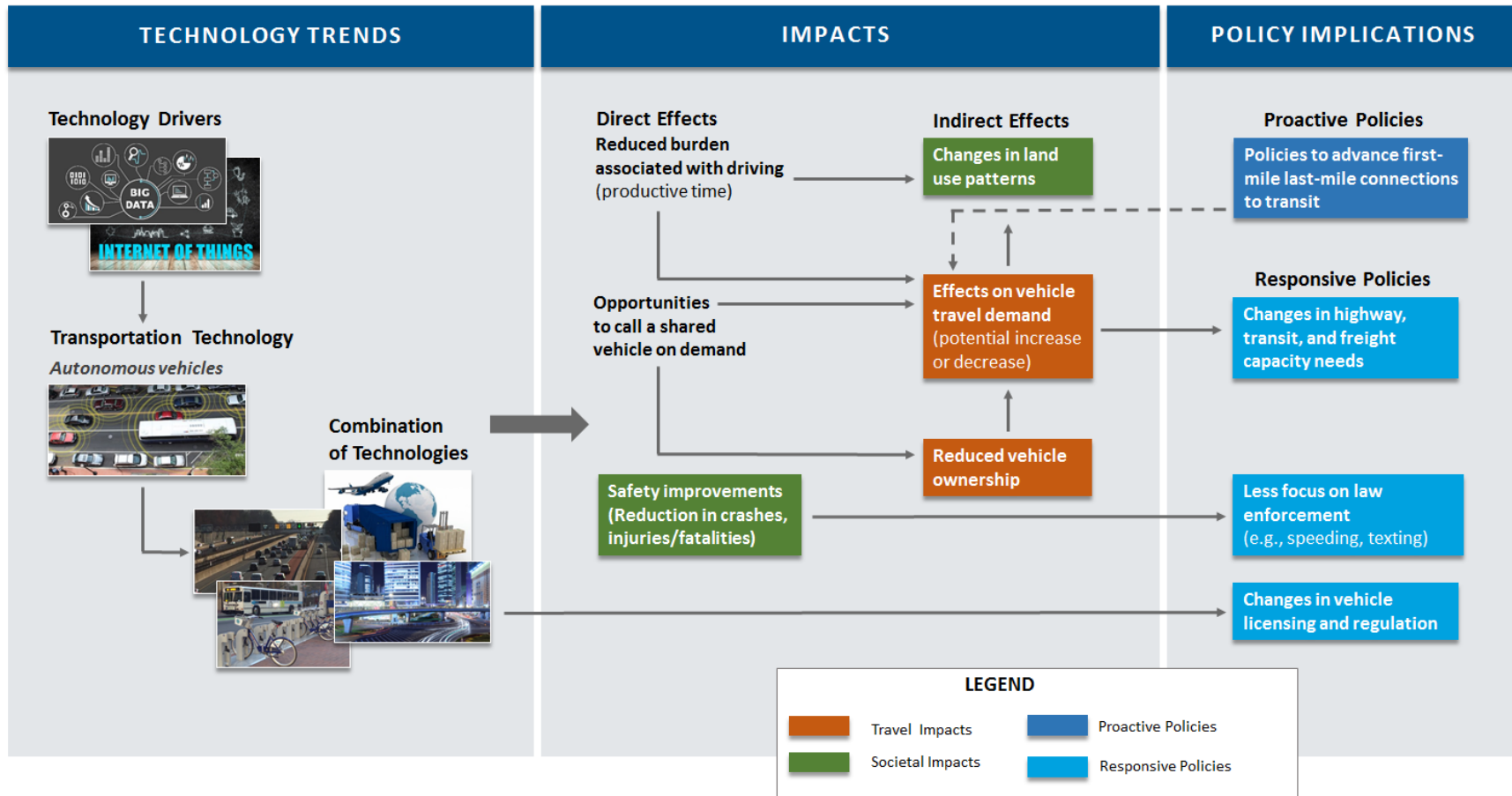


Figure 3-3. Framework for Exploring the Impacts of Technology Trends and Policy Needs



4 POLICY IMPLICATIONS

Given the important implications of technology on travel, infrastructure needs and funding, employment, and society in general, there are a wide array of important policy implications to consider. This chapter first discusses *general policy implications*, which are likely to apply to communities across the U.S., and some of which will need to be addressed at a federal level or by states across the country. It then develops recommendations for *Atlanta region specific policy focus areas*, recognizing the unique attributes of the Atlanta region and its regional goals. Both sets of policies were developed through evaluation of current literature, expert interviews of 12 industry leaders, and input from members of the Project Advisory Committee.

4.1 General Policy Implications

In considering policy implications of transportation technology trends, as noted earlier, two primary types of policy issues were identified in relation to emerging technologies:

- **Responsive policies:** Some policies will be needed in response to new transportation technologies. These policies may be a response to expected impacts, but they could also be anticipatory or enabling to support the adoption of new technologies. In relation to vehicle automation, changes in vehicle standards and licensing policies will likely be needed. Changes in transportation funding mechanisms will be needed as shifts toward electric and alternative fueled vehicles are expected to result in a decline in traditional gas tax funding. It will be important for transportation agencies to develop policies to prepare for these anticipated effects.
- **Proactive policies:** Other policies may be implemented specifically to help shape positive outcomes or reduce the potential for adverse impacts associated with technologies. Particularly in cases where a technology may have adverse or uncertain impacts, proactive policy choices could be implemented to help shape the future outcomes of the technology. The impacts of new technologies on travel demand are uncertain, so policies could be designed at a national, state, or regional level to apply technology in ways that encourage high occupancy modes.

Table 4-1 presents a list of general policy implications of the technology trends, focusing on policies that will need to be considered to react to or support the technology advances.

Table 4-2 includes a list of proactive policies to help support positive outcomes of the technologies.

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: Overview of Trends and Policy Implications



Table 4-1. General Policy Needs or Implications in Response to the Technology Trends

Category	Topic	Policy Need or Implications
Vehicle and Licensing Regulations	Vehicle standards	Requirements for testing and verification of vehicle software, cybersecurity, and data management may be needed in addition to existing Federal Motor Vehicle Safety Standards (FMVSS). FMVSS adapted to address new vehicle designs, materials and propulsion systems.
	Vehicle technology	New regulations for DSRC Technology use in light vehicles in the near future. More broadly, the FCC's determination of the availability of dedicated 5.9 Ghz DSRC spectrum will drive adoption of such technology in vehicles and applications.
	Licensing requirements	Shifts toward autonomous vehicles will likely necessitate changes in driver licensing requirements. Regulation of AVs is being advanced at the state level, many of which have started proposing and implementing changes to their policies and laws regarding AV technology. ⁹⁰
	Ridesourcing requirements	Enhanced policies may be needed related to operation of TNCs, including standards for safety, fares, and accessibility.
	Liability and insurance	As higher-level vehicle automation becomes more of a reality, legal structures to define clearly who is liable for crashes and damages, and how autonomous vehicles will be insured.
Drone Regulations	Air space regulation	Updates to the Federal Aviation Administration's (FAA) rules on small unmanned aircraft ⁹¹ to reflect on-going changes in technology and standards as drones continue to proliferate, particularly in relation to the legal/available use of air space for drones in the urban and rural environment.

⁹⁰ National Conference of State Legislatures (July 2016). "Autonomous/ Self-Driving Vehicles Legislation." Available at <http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx>.

⁹¹ Federal Aviation Administration, June 21, 2016. SUMMARY OF SMALL UNMANNED AIRCRAFT RULE (PART 107). https://www.faa.gov/uas/media/Part_107_Summary.pdf

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: Overview of Trends and Policy Implications



Category	Topic	Policy Need or Implications
Privacy, Security, and Protection	Privacy	With increased collection and reporting of data (i.e., Big Data), standards adapted to ensure systems and technologies incorporate data privacy, specifically those related to personally identifiable information (PII).
	Cybersecurity	Vehicle, mobile and web applications, and infrastructure technology (e.g. IoT, artificial intelligence (AI) technology) that uses connectivity may be subject to cyber threats. Increasing shifts toward automation and connectivity will increase needs for investment in cybersecurity of transportation networks.
	Law enforcement	In the long-run, shifts toward autonomous vehicles could also shift duties of law enforcement associated with behavioral controls, such as control of speeding, driving under the influence of alcohol or drugs, distracted driving, and aggressive driving.
Data Capture and Management	Open data feeds	Greater reliance on open data feeds from both public and private agencies for information sharing with the public is likely. Support for real-time Application Programming Interfaces (APIs), and standardization of data feeds (like GTFS - General Transit Feed Specification, TMDD - Traffic Management Data Dictionary) will be needed at regional and agency-levels.
	Regional operational collaboration	Greater need for center-to-center (C2C) connectivity with an emphasis on the use of the national Intelligent Transportation Systems (ITS) architecture to define open and non-proprietary interfaces to support regional technology projects, such as ICM.
Transportation Funding	New revenue sources	New sources of revenue identified and implemented to provide funding for transportation infrastructure construction, maintenance, and operations, given shifts toward EVs and fuel-efficient vehicles. This may include shifts toward mileage-based fees, other user fees, and/or local and state taxes.
Transportation Investments and Program Priorities	Infrastructure capacity	Changes in investment decisions and priorities, including potential for less new highway capacity, as technology fits more capacity on the existing transportation system.
	New forms of infrastructure investments	New priorities for infrastructure development and associated policies utilizing technology, including potential for development of AV designated lanes, truck-only lanes, upgrades to pavement markings, and deployment of charging infrastructure for EVs.

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: Overview of Trends and Policy Implications



Category	Topic	Policy Need or Implications
	Impacts on transit	Developments in shared personal mobility may reduce interest in supporting fixed route public transportation and create funding pressures for fixed route public transit systems.
	Impacts on transportation system management & operations (TSMO)	Changes in TSMO priorities, such as less need for investments in 511 traveler information systems, dynamic message signs (DMS), and network detection, driven by evolving private sector models for information collection and delivery, wireless connectivity, and improved vehicle telematics.
	Regional models of technology investments	Coordination between multiple organizations – both public and private sector – to work together around integrated technology concepts, such as pilot projects and smart city oriented programs.
Transportation Planning and Investment Decision-making Processes	Understanding system conditions, performance, and travel behavior	Big Data will support analysis of traveler behavior, resulting in less needs for direct data collection efforts (e.g., traffic counts, travel surveys) to support investment planning, as well as for condition monitoring and performance measurement (e.g., use of drones or smart infrastructure to assess system conditions). Correspondingly, robust systems are needed to manage and process the vast increase in data.
	Public involvement in transportation decision making	Guidance to support use of mobile apps and technology to gather input from the public regarding needs and priorities.
Land Use, Public Street Space, and Urban Design	Public street space	The use of public street space, including consideration of the optimal mix of space for on-street parking, shared use options, and transit services. Potential shifts toward less need for on-street parking associated with AVs and MOD create the potential to repurpose on-street parking to other functions, including loading/unloading zones for freight/package delivery, bicycle/pedestrian infrastructure, or parks.

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: *Overview of Trends and Policy Implications*



Category	Topic	Policy Need or Implications
	Zoning and parking requirements	New zoning requirements for development that reflect reduced needs for parking for privately owned vehicles, more use of shared vehicles, and other technology-enabled options.
Transportation Agency Roles and Functions	Changing roles / public-private partnerships	Transportation agency roles may change from operating many public transportation services to coordinating mobility services. New approaches may be needed to support new and innovative public-private sector partnerships for delivery of mobility services.
	Workforce	New skill sets within transportation agencies - shifts from a focus on infrastructure development and construction to system operations, data integration and analysis, cybersecurity, and other needs.
	Innovative procurement	New technologies create opportunities that are difficult for transportation agencies to procure using standard public sector procurement policies. New ways of doing business in relation to procurement would be helpful in this context.

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: Overview of Trends and Policy Implications



Table 4-2. Proactive Policies that Could be Implemented to Help Support Positive Outcomes

Category	Field	Potential Policy
Advancing Environmental Outcomes	Advancing EV adoption	While new technologies are expected to have a significant and positive impact on environmental quality, policies can be implemented to help advance, promote, and guide the development and deployment of such technologies, such as incentives and public infrastructure for alternative fuels.
	"Green" logistics	Policies can be implemented to support and promote the use of low emission freight vehicles and strategies, such as green supply chain.
Advancing System Performance and Mobility	Support higher vehicle occupancy and non-motorized travel	Even with new shared mobility alternatives, there is potential for increased vehicle travel. Policies to reduce vehicle travel by leveraging technology could include pricing incentives, such as toll or parking credits for using higher occupancy vehicles, and regulatory requirements such as site-based or employer-based trip reduction ordinances.
	Support fixed route transit	New shared mobility options have some potential to detract from transit use. Policies to support public transit could include pilot initiatives that seek to deploy new technologies to provide better first-mile/last-mile access to transit, and payment options and pricing strategies to encourage connections to transit.
	Support off-peak deliveries and travel	Policies, such as ones providing incentives, can be implemented to support the use of off-peak deliveries. For passenger travel as well, incentives can be deployed to encourage shifts to off-peak times and routes.
Supporting Vibrant Urban Centers	Policies to support smart growth	With high uncertainty of the impact of the new mobility and technology alternatives on travel behavior and land use, policies to help steer development toward urban centers could mitigate potential adverse impacts. [This is related to policies already identified above, but could go farther, such as development of incentives or density bonuses for provision of shared use parking or transit/shared use fares.]
Advancing Equity	Accessibility	While many technology trends will enhance accessibility for disadvantaged populations, some groups could be left out. Policies and programs can help to ensure that new services and technology are accessible to all, including those who do not have access to new forms of payment (i.e., not everyone may be able to use e-payment linked to credit cards and/or bank accounts).

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: *Overview of Trends and Policy Implications*



Category	Field	Potential Policy
	Non-discrimination	Policies could help to ensure that new services provide fair and equitable access across all sectors of the population, particularly for private sector operated services; this may include issues surrounding the American with Disabilities Act (ADA) requirements as well as Title VI in relation to service provision and service changes.
Advancing Workforce and Economic Development	Driver workforce transition	Changes to the job market for drivers are expected as the system shifts towards automation. Policies can help to guide a sustainable progression of the transition from existing work schemes towards new ones.
	Advancing innovation	Institutional structures and partnerships could help to promote economic development and innovation in the development and deployment of technology within regions, based on unique areas of expertise and competitive advantage.



4.2 Atlanta Specific Policy Focus Areas

In identifying regional policy implications, efforts were focused particularly on policies that the region could proactively advance in order to support the region's vision for the future. Just as the region's long range plan attempts to ensure metro Atlanta's future success and improve the region's quality of life, the technology policies identified here aim to achieve the three themes of the Region's Plan:

- Provide **world-class infrastructure** – Ensure a comprehensive transportation network, incorporating regional transit and 21st century technology.
- Build a **competitive economy** – Build the region as a globally recognized hub of innovation and prosperity; and develop a highly educated and skilled workforce, able to meet the needs of 21st century employers.
- Ensure the region is comprised of **healthy, livable communities** – Develop additional walkable, vibrant centers that support people of all ages and abilities; promote health, arts, and other aspects of a high quality of life.



More than simply policy implications or impacts, this document recommends six policy areas of focus, including potential proactive policy choices that could be moved forward to help shape the future outcomes of technology trends, as shown in Figure 4-1.

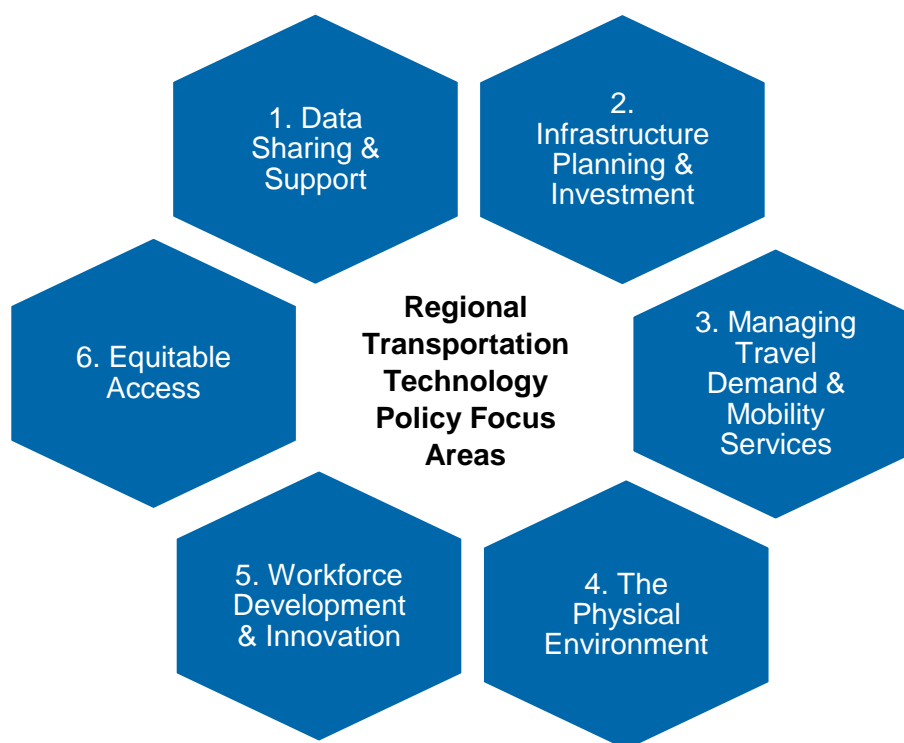


Figure 4-1. Technology Policy Focus Areas for the Atlanta Region



Note that the ordering of these policy areas does not represent a priority ranking. Each of these policy areas are interrelated and are mutually supportive. While many of these policy areas are of interest and concern nationally, they offer specific opportunities at a regional scale for the Atlanta region to implement policies that anticipate and respond to technology trends in support of the region's vision and goals.

Each of these policy areas address both passenger and freight movement, and are discussed below.

4.2.1 Data Sharing and Support

The pervasive availability of data creates substantial opportunities within the transportation sector to enhance planning, operations, and system management. However, there are challenges to harnessing the power of big data. So much of new big data sets are proprietary and the skills needed to make actionable sense from it are not currently being addressed in our transportation planning institutions.

Policy Need: Facilitate data sharing and integration amongst public agencies and between the public and private sectors while addressing the sensitivities of data privacy.

Potential Policy Actions

- Have ARC play a key role in facilitating regional collaboration across partner agencies, including Georgia DOT, Metropolitan Atlanta Rapid Transit Authority (MARTA) (public transportation operator in Atlanta), and Georgia Regional Transportation Authority (GRTA) (oversees mobility in metro Atlanta), and with private sector data providers, to enhance use of data for planning and operations functions. Private vehicle, freight vehicle, transit, and MOD services vehicle data should all be considered.
 - Identify best practices for state and local laws regarding data sharing.
 - Identify the various types of data being collected, analyzed, and shared.
 - Define what data can be standardized and shared to the general public.
 - Develop a standard data sharing agreement that outlines privacy guidelines.
- Have ARC analyze the potential of proprietary data from location data, freight data, and consumer data to improve modeling inputs.
- Enhance operational data sharing through a regional forum for collaboration for enhanced system management and integration of advanced data into integrated corridor management and active management projects.
- Ensure safety and security of future data sharing portals among partner agencies and private industry partners. Any data that is collected directly from consumers or the freight industry should be well secured and not sold but rather aggregated and encrypted before analyzing internally and sharing externally. Any new data-sharing portal established for data sharing must be secure as best practices in software development demands.

4.2.2 Infrastructure Investment and Planning

Transportation technology trends are expected to have important implications on transportation infrastructure investment needs through changes in travel demand and enhancements of the effective capacity of existing infrastructure. New technologies will also enable new approaches to transportation system management and potential new investment strategies and policies,



such as investments in connected V2I projects, the creation of AV lanes, and the development and implementation of smart infrastructure. Technologies are also expected to significantly reduce traditional funding sources for transportation investment via fuel taxes.

Policy Need: Ensure appropriate investments in transportation infrastructure and technologies to take advantage of new and emerging technology trends and to prepare for changes in travel demands, investment needs, and revenue sources.

Potential Policy Actions

- Incorporate technology scenarios (addressing trends such as CVs and AVs, shared mobility options, and changes in freight and logistics) into future regional, corridor, and local transportation and land use planning efforts (including Transit Oriented Developments (TODs)), building on the existing efforts being undertaken through the Strategic Highway Research Program (SHRP2). Specifically:
 - Explore how changes in technologies will affect the performance of the transportation system to help prioritize how funding is allocated.
 - Identify specific outreach and education needs for the public and decision makers as a component of future transportation planning and project development processes.
- Identify innovative technology applications in planning and project development studies, such as advanced signal timing, road striping, managed lanes, and active multimodal traveler information systems to fill potential project gaps between today's environment and the deployment of new vehicle technologies. Identify promising technologies for smart infrastructure deployments that reduce energy consumption. Integrate analysis of advanced technologies into regional and local planning processes, such as:
 - Countywide Comprehensive Transportation Plans,
 - Livable Centers Initiatives,
 - Regional and local freight plans,
 - Corridor plans, and
 - Any future "smart cities" program that may be developed.
- Provide planning support, marketing, incentives, or funding assistance to encourage rapid adoption of new vehicle technologies that provide significant freight and public safety and environmental/health benefits (e.g., EVs).
- Identify key barriers to funding and advancing technologies through existing funding and procurement processes, including identifying specific federal, state, and local funding restrictions, procurement limitations, or other legal blocks.
- Fund regional pilot projects and research to advance the adoption of new technologies or to support application of technologies to address issues such as a first-mile/last-mile connection to transit.
- Incorporate the use of technology into project prioritization and programming processes. Give priority or higher score rankings to projects that demonstrate applications of new technologies.
- Develop regional support for new funding mechanisms to develop, maintain, and operate transportation infrastructure that shifts away from traditional motor fuels. These efforts may include:



- Participation in federal- or state-level policy discussions,
- Analyses to demonstrate anticipated effects of technologies on revenue streams in relation to needs, and
- Exploration of innovative public-private partnerships.

4.2.3 Managing Travel Demand & Mobility Services

While technology trends like AVs are anticipated to improve transportation safety significantly, they also have the potential to increase vehicle travel. Meanwhile, trends in increased shared mobility and on-demand mobility options have the potential to encourage higher vehicle occupancies that could mitigate traffic congestion but could also erode public transportation services. Given the uncertainty of the impacts of technologies on travel demand, policies to encourage increased vehicle occupancy and greater transit usage would be supportive of regional goals for world-class infrastructure and healthy and livable communities. Efforts to advance transportation safety through technology also should ensure a focus on pedestrian and bicycle safety.

Policy Need: Apply advanced technologies to actively manage travel demand and optimize system performance, with a focus on supporting higher occupancy vehicle use and fixed route transit to mitigate congestion and improve safety.

Potential Policy Actions

- Explore on-going advances in traveler mobility services and technologies. Lead efforts to advance one-stop access to information about the full array of travel choices, travel times, and costs.
 - Incorporate TNCs as part of the trip in regional transportation education and include them on trip planning features, websites, and apps.
- As new technology implementation projects are introduced, emphasize safety as a top priority, particularly in relation to non-motorized modes (pedestrians and bicyclists). This may involve providing funding for safety education for all audiences and working to ensure that safety for non-motorized modes is incorporated into pilot programs and projects addressing ICM, CVs and AVs, and other technologies.
- Advance efforts to support a seamless use of technology to pay for mobility services, including public transportation in relation to other available services.
- Encourage use of technology innovations to support demand management and system management, including dynamic use of financial incentives and gamification to encourage use of higher occupancy modes of travel, off-peak travel, and utilization of less congested routes, including during special events and other disruptions.
 - Work with the State Road and Tollway Authority (SRTA) to incentivize off peak travel and ride sharing through the managed lane system.
- When providing federal funding or seeking grants, prioritize shared use mobility strategies that involve HOVs (i.e., UberPool, rather than the use of UberX) and are supportive of and link to public transportation (i.e., support better first-mile/last-mile connections to transit).

4.2.4 Physical Environment

Autonomous vehicle technology has the potential to encourage suburban/exurban sprawl, which



would work against many of the region's existing goals associated with healthy, livable communities. Moreover, changes in vehicle technology and shared use mobility options are expected to have potentially significant effects on vehicle ownership, parking needs, demands for access to public road space for shared use mobility services, air quality, and alternative fuel consumption which will need to be addressed within local zoning, parking policies, and infrastructure deployment.

Policy Need: Develop policies that address changing needs in relation to use of public right-of-way, zoning, and urban form due to technology trends to support livable communities.

Potential Policy Actions

- Provide technical assistance to local governments for updating land use policies, building design standards, and changing parking guidelines, potentially through the Community Choice program.
 - Address options for adaptive reuse of parking structures for both existing parking structures and newly planned structures.
 - In coordination with healthy, livable communities' policies, create a visionary roadway and parking guide that showcases roadway designs for automatic vehicle identification (AVI). This guide should incorporate all modes and discuss impacts on parking and resulting changes to parking requirements.
- Provide tools to address increasing local freight deliveries. Require use of tools as a condition of new developments to assess regional impact.
- Integrate advanced technology considerations into an update or new generation of the Livable Centers Initiative (LCI) program, building on successful applications and lessons learned from the Smart City Challenge and other advanced technology initiatives that support environmental stewardship, community mobility, accessibility, safety, and quality of life.

4.2.5 Workforce Development and Innovation

Emerging technologies will continue to alter employment opportunities in many sectors, potentially resulting in job loss in some industries such as freight delivery. However, the Atlanta region is home to leaders in the logistics and telecommunications industries as well as world-class universities. Policies encouraging cross-industry collaboration can foster increased economic development opportunities to make the Atlanta region into a hub of innovation for transportation technologies, and support the growth of high-paying jobs in new technology fields. Moreover, policies connecting universities and trade schools to the private sector will ensure the workforce is prepared for the changing workforce needs, including jobs lost through automation.

Policy Need: Pursue efforts to make the Atlanta region an innovation hub in the development and deployment of transportation technologies and to prepare the workforce for the skills of growing fields.

Potential Policy Actions

- Bring together local jurisdictions who will jointly provide regional support for the development of transportation technologies, as well as industry organizations, the private sector, and researchers to focus on building upon and catalyzing innovation in



industry clusters, such as logistics and telecommunications.

- Create a regional task force dedicated to regional collaboration and development of pilot projects for technology deployment. Work with key partners, such as the Metro Atlanta Chamber of Commerce, universities, and lead private sector firms to develop this group and spearhead program efforts. Task force activities could include:
 - Review how the finalists for the Smart City Challenge collaborated to identify and achieve participation from valued stakeholders.
 - Identify how to systemically catalyze innovation in certain areas/industries, such as logistics.
 - Invite researchers to determine how to implement their research.
 - Create partnerships with private industry to lead the way in CV and AV deployment.
 - Set up test areas to try out AV, potentially piloting with golf carts and gather before and after data.
 - Identify incentives for technology companies to come to the Atlanta region.
- Gain an advanced understanding of existing logistics infrastructure, in regards to freight tracking, shipping, and warehouse equipment maintenance and the timelines for the adoption of emerging technologies. Create comparisons with the national marketplace.
- Recognize the changing job marketplace in freight and logistics and work with workforce development organizations to provide training, education, and placement.

4.2.6 Equitable Access

While many technology advancements are likely to support improved accessibility for those with disabilities, the elderly, and low-income and minority communities, there are potential barriers to participation. For instance, unbanked households face challenges in using new app-based mobility services that require e-payments. Shifts toward private sector mobility services and shared use options may leave out some communities and do not have the same safeguards for public access and nondiscrimination as public services.

Policy Need: Support equitable outcomes for low-income and minority groups in regard to rapidly changing transportation technologies, with a focus on reducing per person transportation costs and ensuring all communities have access to key technologies.

Potential Policy Actions

- Identify and develop programs to support access to new mobility services by unbanked and low-income households and reduce the likelihood of a TNC user to not be picked up due to driver based on race and/or gender discrimination.
- Develop policies to ensure equitable pricing of services and access for disadvantaged communities.
- Conduct analyses to assess environmental justice and equitable access to transportation services by low-income and minority populations. Incentivize programs or develop pilots in areas with concentrated low income and minority populations, as warranted.

4.3 Implementation Mechanisms

Policy implementation is crucial to successfully address technology changes and fulfill the goals of the Atlanta Region's Plan. Many of the policy needs and potential policy actions identified



above do not operate in isolation and would benefit from a coordinated regional focus on technology deployment. The following implementation mechanisms will connect the focus areas addressed above.

- **Fund pilot programs to advance technology deployment.** Pilot programs can bring together multiple concepts, such as efforts to develop and support mobility applications that incorporate data sharing across multiple entities, that provide improved first-mile/last-mile transit connections, and that are designed to support equitable access to disadvantaged population groups, while also addressing data privacy and sharing across entities.
- **Develop an on-going regional forum or task force around transportation technology innovation.** This group would facilitate collaboration across industries and sectors and have a goal of advancing the Atlanta region as a hub of innovation. This group could also provide direct feedback on the feasibility of data sharing, the outcomes of ongoing pilot projects, and the challenges and successes of integrating new technology into existing infrastructure.
- **Develop partnerships and visionary concepts to help prepare the region to compete for potential future federal discretionary grants or secure private sector funding.** Over the past several years, there have been a number of significant federal discretionary grants, such as the USDOT's Smart City Challenge, FTA's Mobility Sandbox initiative, FHWA's Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Initiative, and the DOT's Accessible Transportation Technologies Research Initiative (ATTRI). Collaborative efforts among transportation agencies at multiple levels, as well as with the private sector and universities, has been an important element of success for some of these awards. Development of Atlanta region-specific concepts and test-beds would be useful to help generate regional support for and partnerships necessary to effectively compete for funding.



5 CONCLUSION

Mobility for people and freight is expected to undergo a dramatic transformation over the coming two decades. The pace of change – enabled by big data and enhanced analytical capabilities – is likely to affect not only the vehicles that people use, but also create new models for mobility services, new freight distribution patterns, and enhanced system management capabilities. The impacts of these changes are likely to be vast – from potentially dramatic improvements in road safety, to increased mobility and access for disabled populations, to cleaner and more sustainable transportation. At the same time, many of the impacts are highly uncertain, and there could be significant adverse consequences on vehicle travel demand, land use patterns, and infrastructure investment needs that are not yet fully understood.

As the Atlanta Regional Commission and its partners in the region conduct short- and long-range investment planning, there is an increasing recognition that it is not enough to forecast changes in demographics, land use, and travel demand. There needs to be a broader consideration of these potentially disruptive and transformational technologies in long-range and short-range transportation planning and policy discussions.

The Atlanta region has recognized this challenge, and through this study has identified six areas of technology policy focus, as well as implementation mechanisms to take advantage of evolving technologies to support regional goals. Through the implementation mechanisms identified in this report – including testing combinations of technologies in pilot settings, developing an on-going regional forum around transportation technology innovation, and developing partnerships and visionary concepts – the Atlanta region will be able to prepare for the impact of these technologies. Even more importantly, the region will be able to proactively advance technology investments, priorities, and partnerships that will provide a foundation for enhancing the economy and quality of life of the Atlanta region in the future.



APPENDIX A: INTERVIEW PARTICIPANTS AND SAMPLE QUESTIONS

Interview Participants

Table A-1 lists the different interview participants that provided their input for this document.

Table A-1. List of interviewees.

Interview Participants
1. Martial Hebert, Professor at the Robotics Institute, Carnegie Mellon University
2. Henrik Christensen, Director of Institute for Contextual Robotics, UC San Diego
3. Jennifer Carter, Senior Business Development Manager, HERE
4. Steven Bayless and Brendon Hemily, ITS America
5. Mike Burgiss, Vice President of Mobility Services, Cox Automotive
6. Michael Zeto, Executive Director, AT&T Smart Cities
7. Andrew Salzberg, Global Mobility Policy Lead, Uber
8. Emily Castor, Director of Transportation Policy, Lyft
9. Jannine Miller and Sandy Lake, Director and Associate Director, Center for Innovation, Georgia Department of Economic Development
10. Kevin Dopart, Managing Director, ITS Joint Program Office, U.S. Department of Transportation
11. Don Francis, Coordinator, Clean Cities-Georgia
12. Shailen Bhatt, Executive Director, Colorado Department of Transportation
13. Joshua Schank, Chief Innovation Officer, Los Angeles Metro

Sample of Interview Questionnaire

The following questions were used to guide the conversation when interviewing each of the participants listed above:

- What technology-related trends have you seen in the transportation industry in your field of work in the past 5 to 10? What technologies or technology changes are having the most significant impact on your field today? (In particular, are there some not mentioned in the literature review that are worth noting?)
- How are these technologies impacting the transportation industry, business, and/or society? What are the most important impacts, and why? (e.g., on personal mobility, safety, quality of life, or other effects? how agencies manage or operate transportation services; how companies do business?)
- What are the emerging/new technologies and trends that are likely to have significant impacts on transportation and mobility in the future?
 - Over the short-term (5 years or less)?
 - Over the next 5 to 15 years?
 - Over the next 20 years or so?
- What types of changes or impacts are expected to be most substantial from these technology trends? Consider:
 - Impacts on society (e.g., land use, mobility, safety)?

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: *Overview of Trends and Policy Implications*



- Impacts to transportation agencies and services providers?
 - Impacts to businesses (e.g., freight shippers, customer expectations)?
- How important will these trends be on changing current practices (for the general public, for the private sector, for the public sector)?
- Are policies currently in place hindering or supporting the ability to adopt new technologies? Or to respond to these technologies? What types of new policies do you think should be explored to prepare for or respond to these technology trends?
- Can you provide any perspectives on policy implications for the Atlanta region specifically? Or how a region such as the Atlanta metro area could position itself to take particular advantage of new technologies to support the economy and quality of life for its residents?

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: Overview of Trends and Policy Implications



APPENDIX B: TRENDS ANALYSIS

Technology / Trend	System Users Affected		Travel-related Impacts						Societal Impacts				Employment		Infrastructure	
	Passengers	Freight	Reduce Vehicle Ownership	Travel Choices - Enhance Transit and Other Options	Reduce Vehicle Travel Demand	Reduce Traffic Congestion / Travel Times	Improve Reliability	Reduce Travel Costs	Land Use - Strengthen Walkable, Vibrant Centers	Safety - Reduce Fatalities and Injuries	Environmental Quality - Improve Air Quality, Reduce GHGs	Equity - Increase Accessibility for Disabled/Disadvantaged	Direct employment	Economic Development - Opportunity to be a hub of innovation	Wear and Tear - Reduce Infrastructure Maintenance	Investment Needs - Reduce Infrastructure Investment Costs
Big Data, Connectivity, and the IoT	●	●	Important Driver of Other Technology Trends													
CVs (Passenger Vehicles)	●		-	-	-	↑	↑	↓	-	↑	↑	-	-	-	-	↓
AVs (Passenger Vehicles)	●		↑	↕	↓	↑	↑	↕	↕	↑	↑	↑	↓	↑	-	↑
Electric/Alt Fuel Vehicles	●	●	-	-	-	-	-	-	↑	-	↑	-	-	↑	-	↓
Shared Mobility Options / Mobility on Demand	●		↑	↑	↑	↑	↑	↑	↑	-	↑	↑	↑	-	↑	↑
Spread of E-Commerce and New Service Models	●	●	↑	-	↑	↑	↑	↑	↓	-	↑	↑	↕	-	-	-
Growth in 3-D Printing and Changes in Logistics		●	-	-	↑	↑	↑	↑	-	-	-	-	-	↑	-	-
CV / AV Freight Vehicles		●	-	-	-	↑	↑	↑	-	↑	↑	-	↓	↑	-	↕
Delivery through UAVs / Drones		●	↑	-	↑	↑	-	↑	-	-	↑	-	↓	-	↑	↑
Improved Traveler Information and Incentives	●	●	-	↑	↑	↑	↑	↑	-	↑	↑	-	-	-	-	-
Mobile Payment Methods	●		-	↑	-	-	-	-	↑	-	-	-	-	-	-	-
ICM and ATDM	●	●	-	↑	↑	↑	↑	-	-	↑	↑	-	-	-	-	↓
Smarter Infrastructure	●	●	-	-	-	↑	↑	-	-	↑	-	-	-	↑	↑	↓

Analysis Codes

↑	Likey large positive
↑	Likely positive
-	Limited effects
↕	Uncertain with potential for positive or negative
↓	Likely negative
↓	Likely large negative



APPENDIX C: BIBLIOGRAPHY

1. Akner, William (2014). 3-D Printers: Changing Transportation as We Know It. Eno Center for Transportation. <https://www.enotrans.org/enobrief/3d-printers-changing-transportation-as-we-know-it>.
2. Alameda County Transportation Commission. (2016). Bay Area Express Lanes. Retrieved from <http://www.alamedactc.org/580express>.
3. Android. (2016). Aindroid Auto. <https://www.android.com/auto/>
4. Apple. (2016). Apple CarPlay. <http://www.apple.com/ios/carplay/>.
5. Atlanta Regional Commission. (2016). "Policy Framework." <http://documents.atlantaregional.com/The-Atlanta-Region-s-Plan/policy-framework.pdf>
6. Atlanta Regional Commission (2016). "Regional Transportation Plan." <http://atlantaregionsplan.com/regional-transportation-plan/>.
7. Atlanta Regional Commission. (October 2016). "Sharpening our Focus: Transportation and Air Quality Committee." <http://documents.atlantaregional.com/taqc/2016/2016-10-13/SHRP%202.pdf>.
8. Atlanta Regional Commission. (September 2016). "Sharpening our Focus: Transportation and Air Quality Committee." http://documents.atlantaregional.com/taqc/2016/2016-09-15/09-15-16_SHRP2_Visioning.pdf.
9. Atlanta Regional Commission. (November 2016). "Sharpening our Focus: Transportation and Air Quality Committee." http://documents.atlantaregional.com/taqc/2016/2016-02-11/2016_WorkProgram_SHRP2.pdf.
10. Automatic website, Retrieved from : <https://www.automatic.com/apps/>
11. Barry, Keith. (August 2015). "In South Korea, Wireless Charging Powers Electric Buses." *Forbes*. August 2015. Retrieved from <http://www.wired.com/2013/08/induction-charged-buses>.
12. Bensinger, Greg. (2012). "Amazon's New Secret Weapon: Delivery Lockers." *The Wall Street Journal*. Retrieved from <http://www.wsj.com/articles/SB10000872396390443545504577567763829784538>.
13. Brown, Chris (2015), "CarSharing: State of the Market and Growth Potential," *Auto Rental News*, March/April, Retrieved from : <http://www.autorentalnews.com/channel/rental-operations/article/story/2015/03/carsharing-state-of-the-market-and-growth-potential.aspx>.
14. Buckley, Chris and Emily Feng. (August 2016). "China's Straddling Bus, on a Test Run, Floats Above Streets." *The New York Times*. Retrieved from http://www.nytimes.com/2016/08/05/world/asia/china-elevated-bus-teb.html?_r=0.
15. Bureau of Transportation Statistics (2015). Freight Facts and Figures 2015. USDOT.
16. Carma, <https://www.qocarma.com/>.
17. 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>.
18. Connected Citizens Program (June 2016). Waze. Retrieved from https://wiki.waze.com/wiki/Connected_Citizens_Program.
19. 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>
20. Eno Center for Transportation and ICF International. (February 2016). "Emerging Technology Trends in Transportation." Eno Center for Transportation Retrieved from <https://www.enotrans.org/wp-content/uploads/EmergingTech.v13.pdf>.
21. Express Lanes 495 and 95. "Pricing." Retrieved from <https://www.expresslanes.com/pricing>.



22. Federal Aviation Administration. (June 21, 2016). *Summary of Small Unmanned Aircraft Rule (Part 107)*. https://www.faa.gov/uas/media/Part_107_Summary.pdf
23. Federal Highway Administration. (2016). Active Parking Management. U.S. Department of Transportation. Retrieved from <http://www.ops.fhwa.dot.gov/atdm/approaches/apm.htm>.
24. Federal Highway Administration. (2016). Active Traffic Management. U.S. Department of Transportation. Retrieved from <http://www.ops.fhwa.dot.gov/atdm/approaches/atm.htm>.
25. Federal Highway Administration. The Smart/Connected City and Its Implications for Connected Transportation. Retrieved from http://www.its.dot.gov/itspac/Dec2014/Smart_Connected_City_FINAL_111314.pdf.
26. Federal Highway Administration. (2016) ATDM Program. United States Department of Transportation. Retrieved from : <http://www.ops.fhwa.dot.gov/atdm/about/overview.htm>.
27. Federal Transit Administration. (2016). "Mobility on Demand (MOD) Sandbox Program. Retrieved from <https://www.transit.dot.gov/research-innovation/mobility-demand-mod-sandbox-program.html>.
28. Federal Highway Administration. (2016). Active Demand Management. U.S. Department of Transportation. Retrieved from <http://www.ops.fhwa.dot.gov/atdm/approaches/adm.htm>.
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/enobrief/shared-use-mobility-the-next-big-thing-in-transportation>.
30. Freight Shuttle International, <https://www.freightshuttle.com/>.
31. French, Steve, Camille Barchers, and Wenwen Zhang. (2015). Moving Beyond Operations: Leveraging Big Data for Urban Planning Decisions. Massachusetts Institute of Technology 14th International Conference on Computers in Urban Planning and Urban Management. Retrieved from http://web.mit.edu/cron/project/CUPUM2015/proceedings/Content/pss/194_french_h.pdf,
32. Frommer, Dan. (August 2016). "This is Amazon's first 'Prime Air' Plane." Recode. Retrieved from <http://www.recode.net/2016/8/5/12382052/amazon-prime-air-plane>.
33. 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/>.
34. Global Workplace Analytics (January 2016). "Latest Telecommuting Statistics." Retrieved from <http://globalworkplaceanalytics.com/telecommuting-statistics>.
35. Goldman, David. (January 2016). "Human-carrying Drone Debuts a CES." CNN. Retrieved August 2016 from <http://www.money.cnn.com/2016/01/06/technology/ces-2016-ehang-drone/>.
36. Google. (2016). Self-Driving Car Project. Retrieved from <http://www.google.com/selfdrivingcar/>.
37. Greenfield, Adam. (2014). Helsinki's ambitious 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>.
38. Hull, Dan, Jeff Plungis, and David Welch. (June 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>.
39. Hyperloop One, <https://hyperloop-one.com/>.
40. Institute of Transportation Studies Berkeley. (2014). Transportation and the Sharing



- Economy. Retrieved from <http://its.berkeley.edu/btl/2014/winter/sharedmobility>.
41. Intelligent Transportation Systems Joint Program Office (2016). Connected Vehicle Research website, Retrieved from http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.htm.
 42. ITS Joint Program Office (2016). Integrated Corridor Management. U.S. Department of Transportation. Retrieved from <http://www.its.dot.gov/icms/index.htm>
 43. Local Motors, <https://localmotors.com/>.
 44. Lyft, <https://www.lyft.com/>.
 45. Marr, Bernard. (March 2015). "How Big Data and the Internet of Things Improve Public Transit in London." Forbes. Retrieved from <http://www.forbes.com/sites/bernardmarr/2015/05/27/how-big-data-and-the-internet-of-things-improve-public-transport-in-london/#2dbe43603ab3>.
 46. Masdar City, <http://www.masdar.ae/>.
 47. McNulty, Mary Ann (2011), Gamification In Travel Management: Is This The Next New Thing To Drive Compliance?, Business Travel News, Retrieved from <http://www.businesstravelnews.com/Travel-Management/Gamification-In-Travel-Management--Is-This-The-Next-New-Thing-To-Drive-Compliance-/?a=proc>.
 48. Metropia, <http://www.metropia.com/solutions>.
 49. 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>.
 50. Minnesota Department of Transportation. (2016). Smart Lanes. Retrieved from <http://www.dot.state.mn.us/smartlanes/>.
 51. MIT Technology Review. (2014). "MIT Technology Review Business Report: The Internet of Things." July/August 2014. <http://www.technologyreview.com/businessreport/the-internet-of-things/download/>.
 52. Mitchell-Keller, Lori. (May 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/>
 53. Missouri Department of Transportation (2016). "Road to Tomorrow." <http://www.modot.org/road2tomorrow/>.
 54. Mobidot, <http://www.mobidot.nl/en/index.php>.
 55. Moovel, <https://www.moovel.com/en/US>.
 56. Morgan, David (2015 June). FAA Expects to Clear U.S. Commercial Drones Within a Year. Retrieved from <http://www.reuters.com/article/2015/06/17/us-usa-drones-congress-idUSKBN0OX1P020150617>.
 57. National Conference of State Legislatures (July 2016). "Autonomous/ Self-Driving Vehicles Legislation." Retrieved from <http://www.ncsl.org/research/transportation/autonomous-vehicles-legislation.aspx>.
 58. National Highway Traffic Safety Administration (2013). "Preliminary Statement of Policy Concerning Automated Vehicles." U.S. Department of Transportation. Retrieved from <http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policy+on+Automated+Vehicle+Development>.
 59. National Renewable Energy Laboratory (2016). E-Roadway Animation. Retrieved August 2016 from: http://www.nrel.gov/transportation/e-roadway_animation.html.
 60. National Research Council of the National Academies (2013), *Transitions to Alternative*



- Vehicles and Fuels*. Washington, DC: National Academies Press.
61. Neumann, Carl-Stefan. (July 2015). "Big Data Versus Big Congestion: Using Information to Improve Transport." McKinsey and Company. Retrieved from <http://www.mckinsey.com/industries/infrastructure/our-insights/big-data-versus-big-congestion-using-information-to-improve-transport>
 62. New York City Department of Transportation. (2016). PARK Smart. Retrieved from <http://www.nyc.gov/html/dot/html/motorist/parksmart.shtml>.
 63. Newcombe (2015). "3 Advances in Transit Technology." Retrieved from <http://www.govtech.com/dc/articles/3-Advances-in-Transit-Technology.html>.
 64. Picker, Leslie and Bill Vlasic. (August 2016). "In Tesla and SolarCity Deal, a Glimpse of Musk's Clean-Energy Aspirations." *The New York Times*. Retrieved from http://www.nytimes.com/2016/08/02/business/dealbook/tesla-solar-city-merger-elon-musk.html?_r=0.
 65. Ramsey, Mike and Cassandra Sweet (August 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>
 66. RelayRides, <https://relayrides.com/>.
 67. Russel, John. (2015). Uber's Latest Experiment Is Uber Cargo, a Logistics Service in Hong Kong. Retrieved from <https://techcrunch.com/2015/01/08/uber-cargo/>.
 68. Scoop, <https://www.takescoop.com/>.
 69. Shaheen, Susan, Cohen, Adam, Zohdy, Ismail, and Kock, Beaudry. (April 2016). "Smartphone Applications to Influence Travel Choices." U.S. Department of Transportation. Retrieved from <http://www.ops.fhwa.dot.gov/publications/fhwahop16023/fhwahop16023.pdf>.
 70. Shaheen, Susan and Adam Cohen, (2014) Transportation Sustainability Research Center – University of California, Berkeley, Innovative Mobility Carsharing Outlook, Fall 2014, Retrieved from <http://tsrc.berkeley.edu/sites/default/files/Fall%202014%20Carsharing%20Outlook%20Final.pdf>.
 71. Smarter Highways, <https://www.studioroosegaarde.net/project/smart-highway/info/>
 72. Société de Transport de Montréal. (2016) "Integrated Mobility." Retrieved from <http://www.stm.info/en/info/fares/special-offers/integrated-mobility>.
 73. Sustainable San Mateo. Retrieved from <http://www.sustainableanmateo.org/home/indicators-report/key-indicator/future-transportation-trends/>. Accessed on August 7, 2016.
 74. Texas Transportation Researcher Technology (2015). New Concepts Drive Future Freight Movement Investments. Volume 51, Number 4. Retrieved from <https://tti.tamu.edu/2015/12/01/technology-new-concepts-drive-future-freight-movement-investments/>
 75. The Economist (2015). "Uber – Driving hard." June 13 edition. Retrieved from <http://www.economist.com/news/business/21654068-taxi-hailing-company-likely-disrupt-delivery-business-driving-hard>.
 76. TriMet, <http://trimet.org/app/index.htm>.
 77. U.S. Department of Energy (2016). "About EV Everywhere." U.S. Department of Energy. Retrieved from <http://energy.gov/eere/everywhere/about-ev-everywhere>.
 78. U.S. Department of Transportation. (November 2015). "Beyond Traffic: U.S. DOT's 30 Year Framework for the Future." Retrieved from <https://www.transportation.gov/BeyondTraffic>.

REGIONAL TRANSPORTATION TECHNOLOGY POLICY DOCUMENT: *Overview of Trends and Policy Implications*



79. United States Department of Transportation. Applications for the Environment: Real-Time Information Synthesis (AERIS) Program. United States Department of Transportation. www.its.dot.gov/aeris/pdf/AERIS_Operational_Scenarios011014.pdf.
80. Urban Engines, <https://www.urbanengines.com/about/>.
81. WeatherCloud. <http://weathercloud.co/>
82. Whelan, Robbie (2014 July). Are Drones the Future of Air Freight? Retrieved <http://www.wsj.com/articles/are-drones-the-future-of-air-freight-1436468089>.