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EMERGING TECHNOLOGY TRENDS IN TRANSPORTATION

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About the Eno Center for Transportation

The Eno Center for Transportation is a neutral, non-partisan think-tank that promotes policy innovation and leads professional development in the transportation industry. As part of its mission, Eno seeks continuous improvement in transportation and its public and private leadership in order to increase the system's mobility, safety, and sustainability.

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TRANSPORTATION POLICY RESEARCH WORKSHOPS

Workshop White Paper Emerging Technology Trends in Transportation

This report was developed to inform a Federal Highway Administration (FHWA) workshop, held in September 2015, exploring emerging technological trends in transportation. This paper provides an overview of select developing transportation technologies and includes a discussion of the policy implications of these new technological trends. The report was co-authored by staff from the Eno Center for Transportation and ICF International.

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Introduction

Technology has been rapidly changing society, the economy, and the way people live, work, and interact with each other. Driven in part by smartphones, a substantial increase in inexpensive computing power, and "the Internet of things," technologies are fundamentally changing access to information and services. Within the transportation sector, the implications of new technologies and models of transportation service delivery are broad and are likely to transform the way people and goods move over the coming decades. Given the life-cycle of planning and the range of impacts of transportation investments, understanding these changes and their potential implications are important to consider when forming federal, state, and local transportation policies.

This paper seeks to provide an overview of technology advances in transportation, focusing on those likely to have important implications for transportation policy. This paper is divided into five categories of potentially transformational technological innovations:

- 1. Autonomous and semi-autonomous driving capabilities;
- 2. New technology enabled models of taxi services and public transit;
- 3. Technology affecting freight and urban goods movement;
- 4. New forms of technology-enabled shared use mobility; and
- **5.** Advances in traveler information, transportation system operations, and travel demand management.

This paper is intended to briefly describe these technological advances and highlight potential policy implications.

Autonomous and Semi-Autonomous Vehicles

Over the past several years, the automobile and technology industries have made significant leaps in bringing computerization and wireless capabilities into motor vehicles, with technologies that allow sensors and software to replace some or all of the human function in driving. Many of these functions are already becoming more commonplace in automobiles.

Autonomous vehicles (AVs),

semi-autonomous features, and connected vehicle (CV) features are enabled by sensors, cameras, and radars, allowing vehicles to wirelessly exchange data with their surroundings. These features allow vehicles to communicate with each other (referred to as vehicle-tovehicle or V2V communications), as well as communications between vehicles and roadway infrastructure, such as traffic signals and toll booths (referred to as vehicle-to-infrastructure or V2I communications).¹

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-driving vehicles), which can be seen as part of a continuum of vehicle control automation.² The following table from NHTSA provides definitions for levels of automation in vehicles, useful for framing discussions around AVs.

Given advances in communications and vehicle technologies, research has explored when and how implementation will impact transportation. New car models increasingly include semi-autonomous features, such as:

LEVELS OF AUTOMATION IN VEHICLES

Level	Automation	Definition
0	No Automation	The driver is in complete control of the vehicle controls, such as the brakes, steering wheel, and throttle.
1	Function-specific Automation	The driver has primary control over operation, but the vehicle has features like adaptive cruise control.
2	Combined Function Automation	At least two primary control functions can work in unison. The driver is still responsible for ensuring safe operation of the vehicle.
3	Limited Self-Driving Automation	The driver can cede full control to the vehicle under certain conditions.
4	Full Self-Driving Automation	The vehicle can safely operate itself; the driver does not need to control the vehicle at all.

Source: NHTSA's "Preliminary Statement of Policy Concerning Automated Vehicles"

- 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 that warn a driver when a vehicle begins to veer out of its lane
- Lane keeping systems, which automatically take steps to ensure the vehicle stays in its lane (unless a turn signal is on in that direction); and
- Systems that brake by themselves in an emergency to avoid a crash.

The time frame for fully autonomous, Level 4 vehicles to be for sale to the public is unclear. Some estimates suggest that there is considerable time to perfect the system: from the next five to ten years to the potential that we will never fully reach Level 4 automation.³ On the other hand, according to researchers at Carnegie Mellon University (CMU), AV technology is more mature than many people realize, and fully autonomous vehicles are likely to be commercially available in the 2020s.⁴ While projections of full automation vary, vehicles on the market continue to have increased autonomous capabilities, and market offerings continue to diversify as automation research proceeds.⁵ Regardless of the timeframe to reach Level 4 automation, factors such as cost, licensing, and liability are all potential barriers to mass adoption of autonomous technologies.

Assuming that these technologies become successful and available to the mass market, AVs have the potential to dramatically change the transportation network and system performance. These changes may lead to significant reductions in fatal crashes and injuries, provide critical mobility to the elderly and disabled, and enhance effective road capacity.⁶ AV technologies also have potential to reduce traffic congestion and fuel consumption.⁷

Beyond passenger vehicles, autonomous heavy-duty trucks could increase road safety and provide opportunities for a more efficient freight delivery system.⁸ In terms of safety, automated freight vehicles could handle long-distance freight, significantly reducing collisions caused by sleep deprivation, inattention, and other factors of human error.⁹ In addition, heavy-duty trucks with autonomous driving capabilities would be able to travel with more compact spacing in traffic, thus increasing the capacity of the roadways while maintaining safety.¹⁰

While AVs offer potential for significant changes in mobility and safety, they raise numerous policy issues for consideration. The following are policy areas that likely need to be addressed as semi-autonomous and fully autonomous driving features become available.

Impacts on Travel Demand, Vehicle Ownership, and Urban Spaces.

The safety and mobility impacts of AVs have potential to create significant changes in travel behavior, especially given the multidecade time horizon in transportation investment planning and policy. By facilitating personal independence and mobility, while enhancing safety and making travel time more productive (for reading, working, relaxing, etc.), CV/AVs could significantly increase the demand for automobile travel. Currently, many older drivers cope with physical limitations through self-regulation, avoiding heavy traffic, unfamiliar roads, night-time driving, and poor weather, while others stop driving altogether.11



Over the past several years, there have been significant leaps in bringing computerization into motor vehicles that allow sensors and software to replace some of the human function in driving.

Liability.

Autonomous vehicles present a number of issues regarding liability and insurance. While experts anticipate that autonomous vehicles will increase safety, accidents will still occur. As pointed out in an Eno Center for Transportation report, human drivers are not generally "held at fault when responding to circumstances beyond their control," regardless of the split-second decisions that they make.¹² However, sensors, algorithms, and software that will come standard with self-driving cars will allow the vehicles themselves to make decisions that are more informed. Courts could scrutinize these decisions.¹³

Additionally, as a report by the RAND Corporation discusses, issues of liability are more likely to fall on manufacturers than consumers. Because the vehicle rather than the driver could be blamed for accidents in AVs, manufacturer liability is greater compared to a non-autonomous vehicle. As such, manufacturers may be hesitant to produce and sell autonomous vehicles on a large scale.¹⁴ However, the RAND report further discusses that several existing solutions reduce product liability for the manufacturer. For example, manufacturers can reduce risk by amending their business model and offer vehicle use as a service rather than a product.¹⁵ Policymakers could also develop legislation and create legal precedents that would reduce liability on the manufacturer. Congress, for instance, could legislate for a reinsurance backstop.¹⁶

As manufacturers face potential liability issues, insurance companies are also encountering potential new territory. Blurring and shifting the lines of responsibility between the human driver and the car manufacturer, AV technology could "change the amount, type, and purchase of automobile insurance" and how liability is defined entirely.¹⁷ As crash avoidance technology continues to improve, insurance companies will have more opportunities to test which components are most vulnerable and costly to collisions.¹⁸

Companies must also consider the emergence of new crash types. As AVs could automatically brake, for example, pedestrians may become acclimated to a self-driving vehicle stopping -- much in the same fashion as people use their hands to stop elevator doors from closing, secure in the knowledge that injury is unlikely.¹⁹ But when a vehicle does not brake and results in fatalities, there is a question of "how the liability system sets incentives to coordinate care among parties."²⁰

Although there is significant progress and excitement about AVs, a recent KPMG survey of insurance companies found that most executives are skeptical of AV technology's pace. Insurance companies anticipate a significant transformation will not occur until 2025 at the earliest, resulting in few insurance companies taking immediate action. With that said, they understood and recognized that if and when this transformation does take place, it would have significant ramifications and require "major changes across all the core functions, from underwriting to claims."²¹

Cyber Security.

Just as the Internet has spawned cybercrime, hacking, and identity theft, the advent of wirelessly connected vehicles creates threats for cybersecurity in the vehicle fleet. Vehicles today already interact with the outside world through a myriad of means: remote key systems, satellite radios, telematic control units, Bluetooth connections, dashboard Internet links, and even wireless tirepressure monitors. Security researchers have demonstrated the ability to hack into a vehicle over the Internet, being able to turn the steering wheel, briefly disable the brakes, and shut down the engine of a 2014 Jeep Cherokee. They also found readily accessible Internet links to thousands of other privately owned Jeeps, Dodges and Chryslers that feature a wireless entertainment and navigation system.²² Experts in cybersecurity indicate that widespread hacks on cars and other connected devices in transportation are destined to come, and the ramifications are potentially severe in a fully connected transportation system.23

Impacts on Highway Design and Infrastructure.

AVs may have implications on highway design, maintenance, and operations. For instance, many AV applications are dependent on clear lane markings. Faded, missing, or old lane markings left visible can hinder the ability of systems, as well as markings covered in snow.²⁴



The time frame for fully autonomous, Level 4 vehicles to be for sale to the public is unclear, but some semi-autonomous features are already available.

Pennsylvania Department of Transportation (PennDOT) commissioned a study to develop a Connected and Autonomous Vehicles 2040 Vision, with researchers at CMU assessing the implications of CVs/ AVs on the management and operation of the state's surface transportation system (assuming that these technologies would be incorporated into all motor vehicles by 2040).²⁵ The study suggested that there are many uncertainties that make investment decisions related to land capacity and highway design challenging. For instance, CV/AV technology will increase the effective capacity of highway lanes via smoother, more uniform and reduced headways as well as more efficient traffic management. On the other hand, travel behavior changes, including induced demand, could adversely affect the extra lane capacity. One of the more important impacts relates to how transportation agencies provide traveler information. With an expanded connectivity network, radio advisories as well as intelligent transportation

system (ITS) message signs might be rendered obsolete, since information that currently is available through ITS message signs would be disseminated directly to the vehicles using vehicle-toinfrastructure (V2I) or vehicle-to-external device (V2X) technologies and on-board units (OBUs). Information provided through ITS message signs could become readily available inside vehicles through original equipment manufacturers (OEMs) and OBUs. In an environment using either cellular or dedicated short range communications (DSRC) technology, the actual ITS message signs and radio advisories might be obsolete; the information transferred through the signs could be transmitted directly from a traffic management center to a cell tower or cloud, then to the vehicle itself.²⁶

Cost.

One of the largest likely barriers to the widespread adoption of semi autonomous and fully autonomous vehicles is the cost of the technology. While there are significant potential benefits to safety and congestion, cost will ultimately be a critical determining factor in terms of achieving these large-scale benefits. since widespread adoption requires affordability. A report by KPMG and the Center for Automotive Research note that the Light Detection and Ranging (LIDAR) systems on top of Gooale's AVs cost \$70,000, and additional costs will accrue from other sensors, software, engineering, and added power and computing requirements.²⁷ Steve Dellenback (KPMG) estimates that most current civilian and military AV applications cost over \$100.000. This is unaffordable for most Americans, with 2012 sticker prices for the top 27 selling vehicles in America ranging from \$16,000 to \$27,000.28

If AV prices become comparable to those for conventional vehicles, research

suggests a ready and willing market. J.D. Power and Associates' survey suggests that 37 percent of persons would "definitely" or "probably" purchase a vehicle equipped with autonomous driving capabilities in their next vehicle, though the share dropped to 20 percent after being asked to assume an additional \$3,000 purchase price.²⁹ And this is assuming that these technologies are proven safe and are able to be significantly reduced in price.

Policies for Advancing Adoption of AVs.

At the federal level, NHTSA and U.S. DOT's ITS Joint Program Office (JPO) have been conducting research on vehicle automation for many years, which has already led to regulatory and policy developments. Areas of research include human factors (evaluating driver/vehicle interaction, allocation of vehicle control functions, and driver acceptance), development of system performance requirements, and addressing electronic control system safety. NHTSA's research will inform agency policy decisions and assist in developing an overall set of requirements and standards for automated vehicles.³⁰

Meanwhile, several states – Nevada, California, Michigan, and Florida – have acted to encourage development of selfdriving vehicles by enacting legislation that expressly permits their operation under certain conditions. Multiple other states are considering or have considered bills.³¹ Further investigation is needed to better understand the appropriate response from federal, state, and local policymakers to ensure safe and efficient deployment of what could be transformational transportation technology.

Technology Enabled Models of Taxi Services and Public Transit

Beyond the potential for autonomous passenger and freight vehicles, another technological development has already had significant transportation impacts is the advent of smartphone applications for taxi and transit services. Smartphones are enabling new business models for interacting with customers to provide transportation services.

Uber is the most well-known transportation network service, operating in 311 cities in 58 countries and providing more than 1 million rides each day as of Fall 2015. Rival services include Lyft and Sidecar in the U.S., Didi Kuaidi in China and GrabTaxi in South-East Asia.³² Consumers have demonstrated high demand for these services because they provide quick and responsive service, and are generally cheaper than conventional taxis.

Codified in California law as "Transportation Network Companies", these services use smartphone apps to allow riders to arrange rides in real-time with ordinary drivers who provide a ride in exchange for payment. These services have sometimes been called "ridesourcing" services, rather than "ridesharing" since they are not designed to reduce vehicle trips.³³ According to research from the University of California Berkeley, these services have directly challenged existing regulations and practices that have long shaped the taxi industry, raising questions about appropriate regulatory and public policy responses.³⁴

However, these companies are increasingly pursuing ridesharing functions, which involve the sharing of one vehicle by multiple riders. UberPOOL and Lyft Line, for example, allow drivers carrying a passenger to add additional passengers riding a similar route. These services are known as "ride-splitting," as passengers can divide the cost of the trip.³⁵

Some services have gone further, creating smartphone enabled transit services. Operating in Boston, MA and Washington, D.C., for example, Bridj provides flexible transit-type services, using shared ride vans that seat up to 14 passengers. The service uses mobile apps to optimize pick-ups, drop-offs, and routing based on demand, at a cost typically higher than a public transit fare but lower than a taxi.³⁶ Using a network of shuttles, Bridj allows a level of flexibility less available in more traditional public transit systems.

Chariot, founded in 2014, is a private crowdsourced bus service that operates fixed service routes. It launches new service routes when a sufficient number of riders reach the threshold to support the route.³⁷ Users purchase tickets or passes, and a mobile app shows the location of shuttles in real time and allows customers to check in for their rides.

Loup, also founded in 2014, and operating in San Francisco, runs frequent service on predetermined routes, under the concept that having reliable service on established routes will provide a more scalable business model.³⁸ While Loup offers predictable services, its routes and vehicle types may change over time, depending on demand. The service started with standard black town cars from partnering local limousine companies, but it can contract larger or additional vehicles based on demand.³⁹

Supporters view ride-sourcing as part of a suite of transport options that serve a previously unmet demand for fast, flexible, and convenient mobility in urban areas. By providing an appealing alternative to driving, it can also potentially reduce auto use, ownership, and environmental problems.⁴⁰ On the other hand, these privatized transit companies have the potential to undermine local transit routes and fare revenues.⁴¹ And while some of the services might provide a dramatic improvement in underserved areas, these benefits may not equally apply to all income ranges. Lower income travelers that do not have access to a smartphone or cannot afford the new services might be left worse off as the traditional transit services they rely upon lose market share.



Smartphones are enabling new business models for interacting with customers to provide transportation services, including taxi services hailed on a phone.

Some of the companies suggest they are not competing with public transit agencies as much as providing overflow options, as many bus routes are overcrowded and cannot accommodate additional passengers. According to Chariot CEO Ali Vahabzadeh: "I think we're actually bringing more commuters back into the transit-first fold as opposed to having them drive to work and congest the streets even more, or commute through Uber, Lyft or Sidecar."42 Moreover, while these companies may expand the transit market, it only expands to riders able to pay a higher fare, raising potential equity concerns. It is also conceivable that local transit agencies could contract with such technology providers to improve service and reduce costs in some parts of their system.

Technology Affecting Freight and Urban Goods Movement

Like with transit, technology enabled models have significant implications for freight. As noted in this report, opportunities exist for the use of autonomous vehicles in freight. Beyond AVs, technologies affecting freight include mobile apps and new transportation service models, drones, and 3D printing.

Impacts of Mobile Apps and New Service Models.

Just as mobile apps have created new business models for passenger transportation, they have the opportunity to also affect urban goods movement. For instance, Uber has begun experimenting with local delivery services, with the aim of becoming as disruptive in logistics and urban deliveries as it has been in the taxi business. In the urban realm, some speculate that Uber could dominate freight services in large part due to the fact that it has lower costs compared to UPS or FedEx, which have to maintain a vehicle fleet.43 Uber is already running a lunch delivery service in Chicago, Los Angeles, New York, Barcelona, Washington, DC, and Toronto. Uber has also launched a service called UberRush in San Francisco, Chicago, and New York, for local deliveries of goods.⁴⁴



Delivery by drone has many applications, but forthcoming regulations will attempt to address some of the externalities and privacy issues

Drones.

Drones are likely to have important impacts on package delivery in urban areas. For example, the Swiss postal system is coordinating with California drone manufacturer Matternet to begin testing the feasibility of using drones for package delivery. Delivery by drones has many applications, including "delivery to peripheral areas" to "transporting emergency supplies."45 Additionally, major retailers like Amazon are prepared to begin using drones for delivery purposes. While the technology is available for delivery by drones to occur, concerns over safety and logistics remain unresolved. However, regulations are forthcoming and will attempt to address some of the externalities and privacy issues associated with drone deliveries.46

3D Printing.

The growing prevalence of 3D printing in manufacturing could potentially impact the transportation system, enabling manufacturing to occur closer to end users.⁴⁷ This could result in reductions in port and air cargo traffic as well as long distance distribution. Additionally, new truck patterns may emerge that will depend on smaller vans rather than larger, heavy-duty trucks.⁴⁸ Currently most 3D printing applications are limited to manufacturing rather than widespread consumer use. But depending on how and if the technology is successfully deployed, it is important for policymakers to consider how this could disrupt current supply chain and freight flows.

Shared Use Economy and New Forms of Shared Use Mobility

Technology has supported the emergence of a new shared use economy, including services like AirBnB, which allows people to rent out their homes or apartments. In the transportation realm, models of shared use mobility -- such as car sharing, bikesharing, dynamic ridesharing, ridesourcing, and ondemand transit -- have gained prominence in recent years.

Shared use mobility "describes the wide variety of new technology-enabled services and tools that give instant access to new services and travel information while complementing traditional modes like fixed-route transit."49 Through the shared use economy, people have access to a wide array of travel options, such as on-demand transportation companies, private transit, public transit, car sharing, and bike sharing. While many of these concepts emerged years ago (for instance, bikesharing first emerged in the 1960s in Amsterdam), their growth is enabled by communications technology that eases reservations, vehicle tracking, and service payment.⁵⁰

These options have seen considerable growth in recent years. For instance, 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 gaining an increasing share of the U.S. market.⁵¹

The "Innovative Mobility Carsharing Outlook," produced by the Transportation Sustainability Research Center at the University of California, Berkeley, reports that carshare numbers have increased from about 448,574 carshare members in the U.S. in 2010 to nearly 1.34 million members in 2014.⁵² While these figures are still a small share of the overall market, new options continue to emerge and car ownership, especially in large cities, is becoming less of a necessity. New service models have also come into existence. RelayRides enables car owners to rent out 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.⁵³

Sharing rides offers significant potential for reduced vehicle travel overall. Modeling work at MIT's SENSEable City Lab, for instance, explored the potential impact that sharing of taxi rides could have on taxi fleet operation in New York City. Results suggest that the total miles traveled by taxis in New York City could be reduced by 40 percent with such a shared taxi system, leading to reductions in service costs, traffic congestion, and emissions, as well as fares paid by individual travelers.⁵⁴



While bikesharing first emerged in the 1960s in Amsterdam, its recent growth is enabled by communications technology that eases reservations, vehicle tracking, and service payment.

According to Dr. Susan Shaheen, the time has come to "no longer think of these services--ridesharing, carsharing, bikesharing, scooter-sharing--discretely but rather as a package of mobility services."⁵⁵ Several arguments can be made for shared use options to be more fully integrated with public transit systems. Helsinki, for example, has set forth an ambitious plan to build an on demand system that would allow users to "purchase mobility in real time, straight from their smartphones."⁵⁶ Helsinki's plan combines all transportation modes into one smartphone application run by a public utility, rather than by multiple private-sector companies.

Regulatory Framework and Local Policies.

With such a variety of technology-enabled mobility options available, a governing framework may be needed.⁵⁷ Companies like Uber or Lyft straddle the line between rideshare service and taxi service, making them difficult to regulate. The California Public Utilities Commission (PUC), for example, rules that these services "are not ridesharing services, entitled to an exemption from regulation," but also do not fully fall into the taxi category.58 Moreover, some local governments, such as those in Boston and Seattle, have amended parking policies to allow for one-way carsharing, whereby users pick up and drop off cars in any legal parking space within the company's coverage area.⁵⁹

Equity.

Equity is critical to consider when discussing technology enabled mobility models as well as the shared use economy.

Many of the emerging technologies for mobility rely on the use of a smartphone, require an Internet connection, and tend to be more expensive than traditional public transit options. Many lower income communities that do not have access to technology might face challenges accessing options, and for-profit companies might also be less inclined to serve them. A PolicyLink report points out that "lowincome communities and communities of color carry the heaviest transportation burdens and could benefit tremendously from" the shared use economy, but these communities rarely use bikesharing and car sharing options.⁶⁰ Policymakers

and planners will be considering how to balance equity and technological expansion as these services are deployed.



Ridesharing is becoming a key mode for accessing airports, as seen here at the Nashville International Airport

The Role of Technology in Traveler Information, Transportation System Operations, and Travel Demand Management

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, transportations system operations, and travel demand management.

Enhanced Traveler Information and Incentives.

Many state and local transportation departments transmit information through 511 mobile applications; transit agencies publish real time information through their own applications; and private application companies, like Waze, serve as an additional resource for travelers. Several opportunities exist for enhancing the real time information provided to travelers. Mobile applications can incentivize travelers to change their behavior. If designed well, a smartphone application can have a profound impact on how travelers choose to transport themselves. For example, the energy sector is rapidly seeing the development of smartphonebased applications for utility company consumers to manage their energy consumption.⁶¹ Simple Energy provides a similar function to utilities but adds social media, competition, and a rewards system to their products.⁶² Many energy management companies estimate significant savings, with Simple Energy reporting that they get an average of 6.7 percent energy savings and over 10 percent during peak times.



Partnerships between technology firms and transportation agencies are opportunities for enhancing the real time information provided to travelers.

In addition to enhanced access to travel information, some smart phone apps 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.⁶³ A start-up company called Urban Engines has been created building on similar concepts aiming to provide analytics, individualized trip plans and micro-incentives.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. As reported on the website, 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

While this has occurred outside the public sector, the idea of working with municipalities is central to the efforts of these start-ups, who position themselves as mobility managers rather than just consumer-focused app developers. However, federal programs can also support these efforts. The U.S. Department of Transportation's Applications for the Environment: Real-Time Information Synthesis (AERIS) Program has performed significant research on the role of technologies in supporting environmental outcomes. The research program developed five operational scenarios (Eco-Signal Operations, Eco-Lanes, Low Emissions Zones, Eco-Traveler Information, and Eco-Integrated Corridor Management), which could provide environmental benefits.67

Optimizing Transportation System Management.

State and local transportation agencies are using technology to better manage and operate transportation systems as coordinated networks. The concept of Integrated Corridor Management (ICM) focuses on improving the transportation network by encouraging the efficient movement of people and goods through institutional collaboration and proactive communication and integration of operations along major corridors (including 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.⁶⁸

A related concept being advanced at the federal, state, and regional levels is called Active Transportation 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).⁶⁹



State and local transportation agencies are using technology to better manage and operate transportation systems as coordinated networks.

The concept of "Smart Cities," defined as "a system of interconnected systems, including employment, health care, retail/entertainment, public services, residences, energy distribution, and not least, transportation... tied together by information and communication technologies that transmit and process data about all sorts of activities within the city," is gaining attention.⁷⁰ Smart cities can use their technological infrastructure in conjunction with mobile applications to support transportation system operations and maintenance. For example, Rio de Janeiro collaborated with Waze in order to collect real-time data about drivers and apply it to their transportation planning systems.⁷¹ Florida DOT and several other states are also using Waze as a key source for providing traveler information. The City of Boston has capitalized on smart technology, using a mobile application called StreetBump to determine pothole locations and uses sensors mounted on building roofs to monitor greenhouse gas emissions.⁷²

Parking Management and Urban Congestion Relief.

Technology can help provide better information to reduce prolonged congestion in urban areas. It is estimated that about 8 to 74 percent of central business district area traffic is a direct result of cruising for parking.73 A prominent effort has been the Congestion and Parking Relief Initiative (CAPRI) in Stanford, California. This program provides cash incentives to Stanford commuters and parkers who shift to commuting during off-peak periods; the approach is now being extended to Bangalore, India and Singapore as well.⁷⁴ Planners and policymakers can use this approach as a low-cost way of improving the operation of their urban streets and roadways.

Policy Implications

Technological advances are likely to have significant impacts on the way people and goods travel over the coming decades, raising policy questions that should be thoughtfully addressed. While the implications for different technologies vary, it is likely that technologies will create significant improvements in traveler safety and will enable different models of transportation service provision. This preliminary research overview illuminates a number of unknowns in federal transportation policy, including:

Is there a federal role in the research, licensing and liability of autonomous technologies?

Self-driving cars, semi-autonomous vehicles, and drones all could provide transformational benefits to the transportation system. These technologies could be accelerated through research funding and regulations that support their licensing and address liability issues. As these technologies could provide substantial national benefits, the federal government can help ensure deployment is done quickly, safely, and responsibly.

Do federal, state and local governments need to rethink their investment strategies?

The bulk of federal program funding is generally geared toward building infrastructure. While infrastructure investment will continue to be an important aspect of any transportation system, technological improvements could provide substantial capacity, safety, and accessibility improvements at a relatively low cost. As currently designed, federal programs do not necessarily encourage implementation of smart technologies at state and local transportation agencies. For instance, federal highway programs and campaigns focused on highway safety may need to be altered to recognize a new safety paradigm associated with autonomous vehicles.

Does the federal government need to restructure transportation planning procedures?

Changes in vehicle travel demand, the effective capacity of roads, and the ways travelers interact with the transportation system will need to be considered in investment planning for both the renewal of existing infrastructure, and the development of newly planned infrastructure, transit operations, and parking. This may have important implications on investment policies and programs at the federal, state, and local levels.

Is there a governmental role in subsidizing the deployment of new technologies?

If autonomous vehicles, traveler information apps, and shared-use systems (among others), prove to be as beneficial as researchers suggest, then there might be a rationale behind subsidizing the additional cost associated with the new technologies.

Is there a need to encourage partnerships between private entities and public agencies?

There has been limited experience with states and localities working directly with

technology data applications to better manage roads and improve planning. Also, most new transportation services such as Uber or Bridj are seen as competitors to existing providers such as taxi commissions and transit agencies. Federal efforts might assist private companies and public agencies in expanding partnerships.

Should the federal government set appropriate standards to assist disadvantaged groups in gaining access to the benefits provided by technology?

New technologies may enhance mobility by providing a range of more economical travel options, but also typically require access to smartphones and payment options that may cost more than traditional road and transit services, raising questions about equity. There might be a federal role in ensuring that all sectors of the population have access to the technologies, and the technologies provide access to economically disadvantaged areas.

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End Notes

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