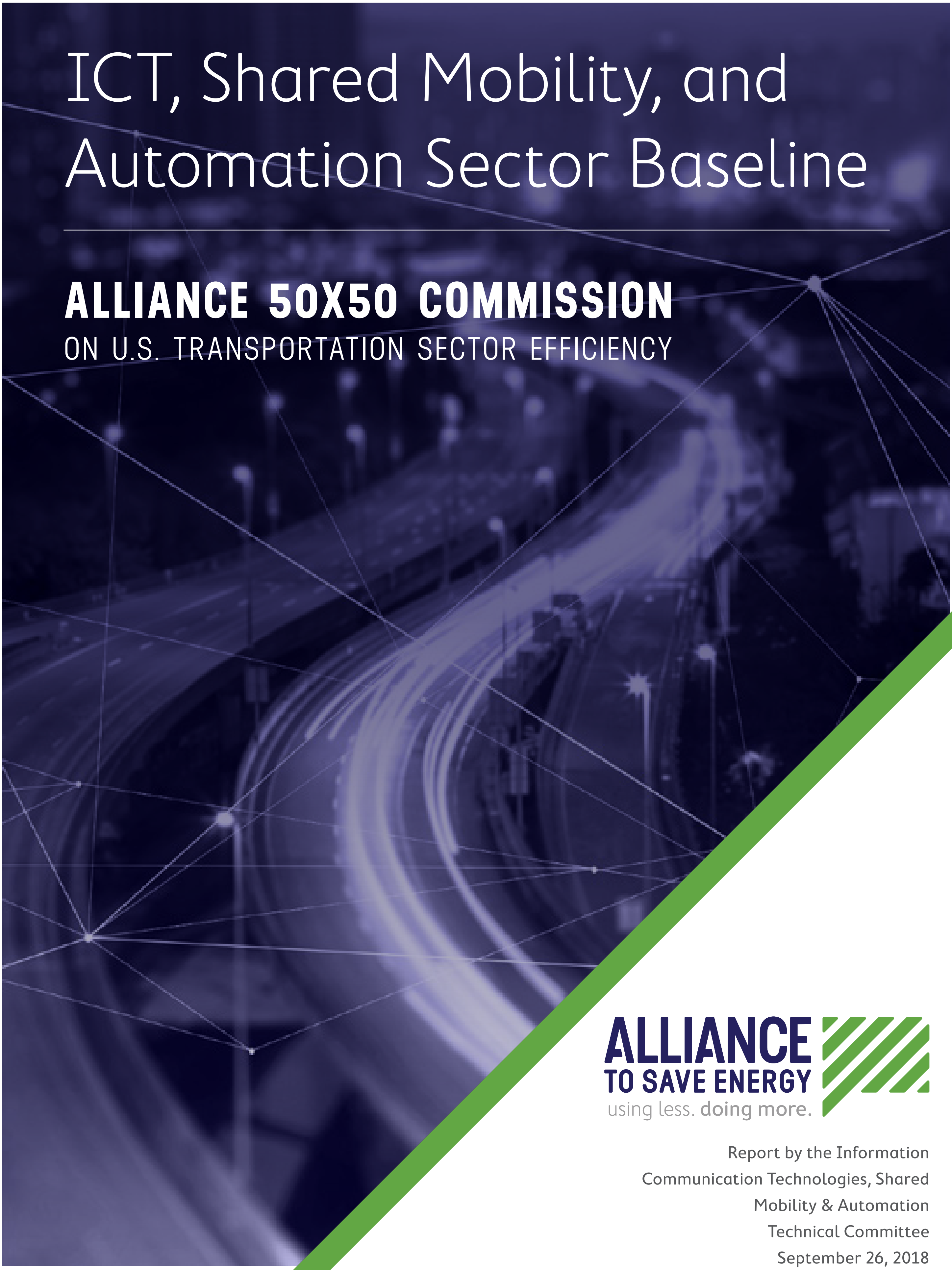
ICT, Shared Mobility, and Automation Sector Baseline

ALLIANCE 50X50 COMMISSION
ON U.S. TRANSPORTATION SECTOR EFFICIENCY



Report by the Information Communication Technologies, Shared Mobility & Automation Technical Committee

September 26, 2018

PREAMBLE

The Alliance to Save Energy launched the 50x50 Commission on U.S. Transportation Sector Efficiency (the "50x50 Commission") to lay out regulatory, policy, and investment pathways to significantly improve energy efficiency in the U.S. transportation sector. Comprising executives and decision makers from a range of key stakeholder groups – including vehicle manufacturers, utilities, federal and subnational governments, technology developers and providers, environmental advocates, and targeted customers – the 50x50 Commission established the goal to reduce energy consumption in the U.S. transportation sector by 50 percent by 2050 on a pump-to-wheel (PTW) basis, relative to a 2016 baseline.

The 50x50 Commission work is complementary to that of the Alliance Commission on National Energy Efficiency Policy, which recommended energy efficiency policies and practices that could lead to a second doubling of energy productivity by 2030. As transportation represents roughly one-third of overall energy consumption in the U.S., the transportation sector offers enormous potential for gains in both energy efficiency and energy productivity.

The outputs of the 50x50 Commission include a foundational white paper that outlines the goals and scope of the Commission's work, a set of five "sector baseline" reports that assess the current state of energy efficiency within the transportation sector, and a suite of policy recommendations outlining the types of government support, at all levels, necessary to achieve the 50x50 goal.

This report, ICT, Shared Mobility and Automation, is one of the five sector baseline reports that identifies the general market trends for efficient transportation technologies and explores opportunities and challenges related to deploying those technologies. This report and the sector baseline reports covering the other four technology areas – Light-duty Vehicles; Heavy-duty Vehicles & Freight; Non-road Vehicles; and Enabling Infrastructure – helped inform the 50x50 Commission's policy recommendations.

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While many Alliance to Save Energy staff assisted with the development of this document, special recognition is given to Laura Van Wie McGrory and Mikelann Scerbo for their significant contributions to this sector baseline.

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INTRODUCTION

Autonomous vehicles (AVs), shared mobility, and information and communications technology (ICT) have the power to transform the transportation sector. At the same time, without a strong focus on energy efficiency, these technologies also have potentially serious implications for energy consumption. Depending on consumer behavior and the prevalence of different levels of automation, studies suggest that the energy impacts of an automated personal mobility sector could span a broad range – from reducing road transport emissions and energy use by nearly half, to doubling them.[1] The large degree of uncertainty surrounding potential increases in vehicle miles traveled (VMTs) due to automation highlights the need to combine planning for automation with energy efficiency strategies. Some studies indicate that automation, electrification, and shared mobility must all be combined to reduce fuel consumption.[2,3,4] Shared mobility – the shared use of a transportation mode, leading to higher vehicle occupancy – helps reduce the number of cars on the road. ICT works as a holistic enabler of system-wide efficiency solutions, including shared mobility and automation, through monitoring and communicating data within and between infrastructure and vehicles.

This report explores the current status of these trends, as well as opportunities for increasing energy efficiency through automation, shared mobility, and ICT, exploring each sector's benefits and synergies with one another, and with electrification.

SUMMARY OF KEY FINDINGS

Minimizing VMTs with the Advent of New Technologies

The rise of autonomous vehicles and shared mobility has the potential to either reduce or increase VMTs and energy consumption; planning for these changes should thus be combined with strategies to advance energy efficiency.

Benefits of Mode Shifting

Shifting away from the individual use of conventional light duty vehicles to less fuel-intensive or higher-occupancy-per-vehicle forms of travel – such as walking, bicycling, riding on a bus or train, or carpooling – will save energy.

Benefits of Transit & Integration with Shared Mobility

Transit continues to provide opportunities to reduce overall transportation-related energy consumption and environmental impacts by shifting passengers away from private cars. Effectively integrating shared mobility services, especially transportation network companies, into the transit network is key for mitigating congestion impacts and increasing the overall efficiency of transportation networks. Effective system planning should complement efforts to increase availability and accessibility of transit along main service routes with measures designed to improve access to point-to-point new mobility services that support other trips.

Benefits of Automation

While the effects of automation on consumer demand for transportation are not yet clear, automation in vehicles has the potential to drastically improve safety as well as to improve fuel economy by about 25 percent through driving optimization and more efficient traffic flow.

Benefits of Smart Growth Strategies

Incentivizing residents to live closer to the core of cities – including through smart growth strategies such as mixing land uses, creating walkable neighborhoods and a range of housing and employment choices, and increasing access to transit – could significantly reduce single-passenger miles traveled, thereby reducing congestion and energy consumption.

Digitization Enables Efficiency

Data stream integration could enable the "tuning" of the mobility system for efficiency. For example, streamlined data collection can offer insight into consumer needs for transportation, while centralized data platforms can enable users to more effectively utilize transit where appropriate and ride-hailing for point-to-point purposes.

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Self-Driving

AUTOMATION

AUTOMATION

This section explores the efficiency opportunities and barriers of fast-emerging AV technologies. The varying levels of automation are referenced using the terminology and definitions from the Department of Transportation (DOT):[5]

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

The Rise of Automation

The anticipated development of automation (see Trends in Automation below) has major potential implications for increased safety and transportation access. Automation can increase safety and reliability by minimizing the potential for human error. This could have important implications considering 94 percent of serious crashes are due to human error.[6] In the trucking sector alone, there were 3,900 crash-related deaths in 2015.[7] Beyond highway and road systems, automation can prevent accidents and may be even more easily implemented in the non-road sector, for example in vehicles that operate in seaports and airports, where the highly controlled conditions of operation and standardization of design and operations create a less complicated environment for the application of autonomous technologies.
In addition to providing safety benefits, the point-to-point service and potential low cost of AVs could enable transportation access to communities otherwise underserved by other transportation options.

While the potential safety and access benefits of vehicle automation are widely acknowledged, the ultimate effects of this trend will depend on how the technology is implemented, the regulatory environment, and market demands. Most major auto manufacturers and technology providers are promising varying levels of automated vehicle capability within the next few years. A 2017 EIA study identified five main challenges required for AV market penetration: technology capability, cost, and cybersecurity; consumer opinion, acceptance, and use; policy and regulation; insurance and liability; and energy and economic impact uncertainties.[8] The discussions below largely focus on the energy impact uncertainties of automation.

Trends in Automation

Private Passenger Vehicles – Automation Trends

Current automated passenger vehicle systems have not been commercialized beyond partial automation. There is no "hands-free" system that is commercially available. Partial automation examples available for retail purchase include the Tesla Autopilot or Audi Traffic Jam Assist.[9,10] All technologies presently sold require the human driver to remain in position to control steering, braking, acceleration and obstacle avoidance. Therefore, today's state of technology remains "hands-on," even if drivers are occasionally permitted to remove their hands from the steering wheel.

Research and development into full automation is being carried out by auto manufacturers and component suppliers, as well as by both established and start-up automation technology companies. Two primary strategies, listed below, are being pursued by innovators. Some are pursuing both strategies in parallel.

1. **Step-by-step approach**
   The step-by-step approach starts with advanced driver assistance systems, providing partial automation where multiple technologies can work together to provide the capability to handle some lateral and longitudinal functions. The next step is enabling several foundational driver assistance systems to function together to achieve conditional automation. At this level of automation, the vehicle is responsible for the data fusion and response that enables self-driving.

2. **Leapfrog to high or full automation**
   Another strategy is to move straight to high or full automation. In fully automated vehicles, the human user is typically only a passenger, not a driver; the car only requires destination information. To date, however, many fully automated vehicles cannot meet existing federal motor vehicle standards because they eliminate steering or foot pedal controls.

Several countries are accelerating their efforts to develop automated vehicles and integrate them with their transportation systems; the U.S. risks falling behind in the vehicle market if it does not keep pace with the progress of competitive countries. For example, Germany passed a bill in June 2017 legalizing automated vehicles; the Japanese government has set a goal of Tokyo becoming a self-driving city in time for the 2020 Summer Olympics; Dubai aims to achieve 25 percent of trips in driverless mode by 2030; and the nuTonomy company set a goal for a fully self-driving taxi fleet in Singapore by 2018.[11,12,13,14]

Transit – Automation Trends

While most national headlines have focused on AV technologies in relation to private passenger vehicles, autonomous technologies have been advancing in the transit industry as well. While most roadway transit vehicles have no automation, there are some transit bus systems already utilizing advanced driver assistance systems or partial automation. In addition, several small manufacturers such as Local Motors, Navya, and EasyMile now offer high automation transit vehicles.[15] Cities and transit authorities across the U.S. demonstrating automation technology include Las Vegas, NV; Arlington, TX; and Baltimore, MD.[16] An automated transit shuttle has been in operation in downtown Las Vegas since November 2017.[17] To further support and advance AV applications and innovations, the Federal Transit Administration (FTA) announced the "STAR" (Strategic Transit Automation Research) Plan in December 2017. Under this initiative, the FTA intends to pursue one to three demonstration projects annually through fiscal year 2022, in addition to pursuing research initiatives that seek to understand consumer acceptance, workforce impacts, and the effectiveness of automated buses.[18]

Freight – Automation Trends

Truck automation technologies are emerging in parallel with the passenger vehicle technologies described above. Freightliner's conditional automation Inspiration truck was licensed for roadway use in Nevada in 2015, and driver assistance and partial automation are expected to be employed in interstate trucking under certain driving and weather conditions within the next two years.[19,20] In addition, platooning exercises (linking two or more vehicles in a convoy using automation technology) are planned for Ohio's Smart Mobility Corridor.[21]

Automation technologies already available in trucks include predictive cruise control and route optimization. Predictive cruise control, which can implement acceleration and shift strategies to maximize fuel efficiency based on foreknowledge of terrain changes, has been available for tractor trucks in recent years and is estimated to save up to two percent in fuel in rolling terrain.[22] Route optimization is another function gaining traction as a fuel-savings technology for commercial vehicles. The United Parcel Service (UPS) employs its On-Road Integrated Optimization and Navigation tool on all U.S. routes and expects to achieve annual reductions of 100 million miles and 100,000 million metric tons of carbon dioxide emissions as a result. UPS plans to deploy dynamic route optimization by 2019.[23]

Full automation trucks are not anticipated on roadways for several years, although driverless trucks are already in use for mining operations in Australia, Canada, and Chile.[24] Toyota's e-Palette concept, described as "transparent cargo or shipping containers on wheels that grow and shrink in size depending on their specific task," demonstrates how autonomous vehicles could entirely change the landscape of commercial vehicles services.[25] In the realm of package delivery, drones introduce another entirely new, automated option to the vehicle mix.

Non-road Vehicles – Automation Trends

Automation may have a stronger influence in non-road vehicles sooner than in other transportation modes due to their highly controlled conditions of operation, and level of standardization of design and operations, which create a less complicated environment for application of robotic and other autonomous technologies. The non-road vehicles category includes services vital to the movement of goods and people and to related industries, including construction, agriculture, forestry, mining, freight transport, and public safety. Generally, these vehicles are driven under controlled conditions, by operators who receive special training and whose compliance with rules and procedures is closely monitored.

In the farm equipment industry, automated technology is already making an impact with the introduction of autonomous tractors. Starting with electrification of the drivetrain, the addition of vision and guidance systems with onboard and remote-control systems allows some existing tractors to be retrofitted to become autonomous. Autonomous Tractor Corporation is a key player driving toward full automation tractors that are capable of 24-hour operation. Their tractors are smaller, lighter, and more easily repairable than conventional models, yielding estimated 25 percent fuel efficiency gains.[26]

Another example of the influence of automation in the non-road vehicles industry is aircraft movement and ground handling operations.[27] Most automation in the near-term will likely focus on automated docking assistance of aircraft to jetways enabled through artificially intelligent vision-based systems. Thyssenkrupp, a diversified industrial group based in Germany, showcased their Smart Docking Assistant at the 29th International Air Transport Association Ground Handling Conference in Toronto in 2016.[28] The Smart Docking Assistant uses technology similar to Park Assist systems in passenger vehicles to automate the bridge-to-aircraft docking process, allowing more precise measurement of risk variables during docking and minimizing damage to airplanes. While overall impact on energy efficiency is likely to be small, there could be significant benefits in passenger safety and aircraft turnaround time due to automated docking assistance.

Energy Efficiency Opportunities & Implications for Automation

Automation could have either a positive or a negative impact on energy efficiency depending on the regulatory environment, how the technology is implemented, market demands, and consumer behavior.

Another factor influencing energy consumption due to automation is the potential future development of on-demand fleets of AVs. Fleets of highly automated vehicles could offer on-demand transportation. These services would likely operate similarly to current transportation network companies (TNCs) such as Lyft and Uber, except the automated vehicles could be used at higher utilization rates. Automated on-demand transportation has the potential to compete with personally-owned vehicles because riding in a self-driven car allows the user to recapture some of the value of their time in transit. However, the cost comparison of automated on-demand transportation versus today's TNC services is still a key research question. While most of the cost of the trip for today's TNC services is for driver labor, the automated fleet vehicles themselves would have higher capital costs and would require additional services such as fleet management, cleaning, and data offloading.

Automation will affect the following key factors influencing energy efficiency:

Fuel economy

According to the Eno Center for Transportation, automation has the potential to improve fuel economy by 23 percent to 39 percent as a result of driving optimization and efficient traffic flow – through such features as adaptive cruise control, traffic lights coordination, notification of upcoming incidents, route optimization, and reduced braking – as well as platooning.[29]

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Platooning decreases the distance between cars and trucks through electronic coupling, with a leading vehicle and multiple following vehicles. Automation can enable platooning to both improve traffic flow and provide vehicle efficiency benefits. In the trucking industry the increased efficiency benefits due to platooning are estimated to be up to 4.5 percent for the leading vehicle and up to 10 percent for the following vehicle.[30]

Potential fuel savings through platooning are higher for tractor-trailers than for passenger vehicles, because of both the high percentage of fuel consumption associated with tractor-trailer aerodynamic drag at highway speeds and the high number of vehicles that belong to sizable truck fleets. Before platooning with unaffiliated vehicles becomes common practice, opportunities to implement more-than-two-truck convoys may be easier to arrange than passenger vehicle convoys. Recent research at the National Renewable Energy Laboratory concluded that 65 percent of truck miles were "platoonable," leading to an estimated 4 percent possible reduction in total truck fuel consumption through platooning.[31]

Congestion, VMTs and Energy Consumption

While automation could reduce congestion through speed and route optimization, it also could bring about increased congestion and energy consumption if it results in consumer demand increases. The net effects on energy consumption from automating passenger vehicles, including on-demand fleets, will depend on a variety of factors that could increase or decrease overall transportation efficiency.

Automation with adaptive cruise control can enable smoother traffic flow to increase lane capacity by up to 80 percent.[32] In addition, the decline in accidents due to automation could reduce congestion by 25 percent.[33] Other scenarios in which automated passenger vehicles could potentially reduce energy use include:

- Users might travel fewer miles using an automated TNC service than they would if they personally owned a vehicle, due to travel being priced on the margin (per trip and per mile) instead of being a capital cost (initial purchase of the vehicle);
- Fleet business managers may attempt to minimize total cost, which could prioritize electric vehicles (EVs) due to their lower fuel and maintenance costs and energy-efficient operation;
- Automated TNC services may cause a reduction in car ownership, leading to lower VMT and to high-density living by removing the need for car garages; or
- AVs could find parking or EV charging stations on their own, which could reduce or eliminate parking time and idling and further reduce congestion and energy consumption.

Nevertheless, congestion and VMTs could increase if AVs spur a significant increase in consumer demand for travel. For example, AVs may create greater willingness by commuters to live farther from work (partly due to increased productivity and comfort in-transit), may increase the demand for delivery services, and generally may reduce travel costs – which could increase miles traveled and thereby increase overall traffic volume. In addition, AVs may result in increased highway speeds due to improved safety, which also could increase energy consumption. Uncertainty surrounding the following additional factors also could potentially lead to an increase in energy consumption:

- The levels of differentiated service and available prices. For example, the extent to which fleets will offer service in large, comfort-focused vehicles with low efficiency.
- Whether fleet operations prioritize efficiency or speed in their operations.
- To what degree self-driving cars integrate with high-capacity, high-quality transit service. Multimodal integration, including connecting automated light duty vehicles to transit hubs, would save energy in land use and community design, as well as through the travel itself (see Shared Mobility section).
- Whether other less fuel-intensive modes, including transit, walking, and biking, are displaced by automated passenger vehicles.
- Whether other delivery technologies, such as drones, will have an impact on automotive fleets.

Space

Automation has the potential to significantly reduce the need for dedicated vehicle parking. With streets, parking garages, and private properties dedicating significant space to storing vehicles, a declining demand for parking spaces represents an opportunity to reallocate meaningful square footage currently allocated to vehicular storage to other uses. This is space that could be allocated to housing stock in downtown areas closer to job centers. Demand for transportation will therefore naturally decline as the VMTs required to service those job centers drops significantly.

Weight

The overall effect of automation on vehicle weight is also uncertain. While the equipment required for full automation could add some weight to vehicles, full automation also could eliminate the need for many vehicle components including steering wheels, foot pedals, and transmission control, which could reduce vehicle weight. In the case of electric automated vehicles, an electric powertrain can further reduce overall mechanical equipment complexity and the number of parts in the vehicle. Still, full automation will require the additional weight of the associated hardware and electrical systems.

While automation presents many opportunities for efficiency, increased VMTs could be an unintended consequence if efforts are not made to mitigate potential increases in consumer demand.[34] Shared mobility, electrification, and system design can work in concert with automation to minimize energy consumption and associated emissions. Full automation systems are expected to integrate with electric and shared fleets and reduce personal ownership.[35] An LBNL report found that integrating shared and automated technologies "could result in decreased U.S. per-mile greenhouse gas (GHG) emissions in 2030 per [automated, shared vehicle] deployed of 87–94 percent below current conventionally driven vehicles … [and] could enable GHG reductions even if total VMT, average speed and vehicle size increased substantially."[36]

The impacts of automation, both absolute and relative, will be different for freight vehicles than for passenger vehicles. Heavy trucks are likely to adopt many automation technologies quickly, in part due to the high potential for energy savings on a per-truck basis, given trucks' high per-mile consumption and high annual miles, which exceed 100,000 miles for a new tractor truck.[37]

Automation opportunities in freight movement also go beyond technologies for individual vehicles and can apply to the way in which loads are distributed to vehicles and across freight modes and routes. Origins and destinations may also change as locations for value-add services and warehousing are reconfigured for efficiency. Today's logistics companies deploy increasingly sophisticated software and data analytics to provide real-time, mode-neutral assignment of multiple clients' loads to the freight network. As such services move to the cloud so that more vehicle and infrastructure options become available to shippers, the need for third-party logistics providers may decline. A highly automated future state for freight transport is captured in the notion of the Physical Internet, a modular goods movement system in which all shippers have direct access to the full freight network.[38] Such a system would maximize opportunities for load consolidation and the efficient deployment of all goods movement infrastructure and services.

In the non-road sector, there are also significant short- to mid-term opportunities for increasing the use of specialized AVs around the aircraft parking area. These vehicles will likely be equipped with sensors for navigation, guidance, collision threat detection, and automated docking to aircraft using visual targets. The automated ground support vehicles are expected to be centrally managed through a network operations center, reducing overall need for human presence around the aircraft and increasing safety and reliability.

Social Considerations for Automation

While automation can improve transit frequency or allow freight trucks to operate during off-peak hours, worker displacement is a major concern in the transit and trucking industries. Transit service frequency is currently limited primarily by the significant operating costs associated with driver personnel. Systems with autonomous transit vehicles could operate at near peak-period frequency throughout the day and week with minimal additional marginal cost, thus increasing the convenience and efficiency of transit travel and mitigating the overall growth in VMTs. Nevertheless, driver's unions have expressed significant concerns about automation. In a December 2016 report on the impact of vehicle automation on workforce in the trucking industry, the Council for Economic Advisers estimated that 2.2 to 3.1 million existing part- and full-time U.S. jobs may be threatened or substantially altered by AV technology.[39]

Still, more studies are required to understand the net impact of vehicle automation on the economy. While automation could eliminate some jobs, it could also have positive economic and workforce impacts by creating new types of jobs, providing job opportunities to those previously not in the workforce, and improving productivity. Transit operators are likely to remain vital in fare collection, customer service, and passenger safety, and the increased market strength and ridership of high frequency transit service may increase the need for such "human-touch" services. In addition, there is a longstanding shortage of truck drivers, due partially to the perceived stresses of long-haul trucking. In a scenario in which autonomous trucks are deployed for long trips and drivers provide their services for short-distance, typically more complex trips could be appealing to both truck drivers and trucking companies.[40]

The perception of automation is another major challenge: eliminating the human interaction may present a barrier to rider acceptance. While experiences in Pittsburgh, PA; Tempe, AZ; and other locales demonstrate that passengers and fellow travelers readily adapt to and embrace autonomous technology, transit riders may still prefer a human operator in order to feel personally secure on transit, or to assist them in using the service or identifying their stop.[41,42] In addition, if a car accident is caused by or involves an AV, then the perception of the AV can potentially take on a longer lasting or more negative stigma than if the car accident was caused by or involved human drivers.[43]

Social and Regulatory Considerations

As automation technologies progress and as business models are tested, there will be numerous social and regulatory issues to address. In some cases, public-private partnerships can facilitate exploration of solutions to these challenges posed by automation.

Government and industry partnerships that socialize potential changes and determine local needs – such as reducing congestion, improving access, lowering emissions, and minimizing parking problems – are critical for understanding how to deploy new technologies without creating a backlash associated with new rules or restrictions.

- Education of consumers, retailers, and government officials can help set realistic expectations about technologies and build awareness of their societal benefits, including improved safety and access to transportation.
- Since automation technology is emerging at a rapid pace, many state and local authorities are not equipped to take proactive steps to guide the introduction of AV technology and develop the appropriate regulatory and policy frameworks. For instance, truck platooning may run afoul of state law regarding highway following distance. In addition, confusion persists about oversight responsibilities among federal, state, and local authorities. At present, the FTA lacks cohesive policies for fully autonomous transit services. Wherever possible, state and local authorities can expand and modify existing laws and definitions to clarify authority over AVs, to ensure consistency in the treatment of AVs, and to treat AVs differently from vehicles without automation where appropriate as the existing policies either may no longer apply for an AV or may not sufficiently cover the new capabilities of an AV.
- As the deployment of automation technology accelerates, the Transportation Safety Board and FTA will need to keep pace with the testing and certification of vehicle safety and capabilities before deployment to the public. Hasty deployments of not fully tested technologies, in the interest of accelerating innovation by automation technology players unaccustomed to automotive regulatory standards, might result in an overall lack of public trust. Furthermore, barriers created in real-world testing can create "blind spots" on edge cases. While testing performance of AVs under a wide range of adverse weather conditions will be very challenging and time consuming, there is an opportunity for transportation authorities to work with private industry to coordinate safe and transparent testing across the myriad driving environments nationwide.

SHARED MOBILITY

SHARED MOBILITY

This section explores the efficiency opportunities presented by shared mobility. The types of shared mobility described in this section include:

- **Ride-hailing**
  The service provided when a customer hires a driver to take them exactly where they need to go. Ride-hailing includes hailing a taxi from the street or using an app to hail a TNC service (see below).
- **Transportation Network Company (TNC)**
  In 2013, the California Public Utilities Commission defined a TNC as a company that uses an internet platform to connect passengers with drivers using their personal, non-commercial vehicles. TNCs can also be known as ride-sourcing, e-hailing, or ride-sharing services. Uber and Lyft are examples of TNCs.
- **Car-sharing**
  Car-sharing is a type of car rental that is designed for users to rent over short periods of time, typically a few hours.
- **Carpooling**
  An arrangement between people to make a trip together in a single vehicle, typically with each person taking turns to drive.
- **Public transit**
  Transportation that provides regular service to the public, but not including school buses, charter or sightseeing services.
- **Microtransit**
  Privately operated, small-scale transit system that provides on-demand, dynamic shared rides and often mirrors select public transit routes.

The Emerging Mobility Ecosystem

New travel options are increasingly available to supplement core public transportation networks. Car-sharing, bike-sharing, and TNC services provide the public with a wealth of new mobility options. For these increasingly complex travel networks to work most effectively, traditional transit must be integrated with new mobility opportunities to create synergistic, sustainable, healthy, and energy-efficient transportation patterns. For example, system planners can complement their efforts to increase availability and accessibility of transit along main service routes with measures designed to improve access to point-to-point new mobility services that support other trips. This integration can help take advantage of the benefits of new mobility services, such as the potential for TNC services to improve access to transportation to underserved communities, while mitigating impacts on energy consumption.

Collectively, these services comprise an emerging mobility ecosystem that could ideally accommodate most trips without the use of personal vehicles. Recent studies indicate that it would be possible to take urban passengers to their destinations with at least 80 percent fewer cars.[44] The development of such a system is an important opportunity for helping to reduce America's overwhelming dependency on personal vehicles for travel. In a survey of shared mobility users across several U.S. transit agencies, the Transportation Research Board found that about 30 percent of shared mobility users reported shedding a vehicle.[45]

The quickly evolving shared mobility market is even reflected in investments by auto manufacturers. In addition to investing in TNC or car-sharing enterprises, traditional auto manufacturers have recently entered tangentially related aspects of the shared mobility market. For example, Daimler formed a mobility services subsidiary, Moovel Group, which acquires transportation-related smartphone application (app) startups. Currently, its portfolio includes route planner RideScout, taxi-booking app Mytaxi, and mobile ticketing app GlobeSherpa.

Highlighted below are examples of shared mobility modes that are trending toward increased options and usership:

TNCs

TNCs are a major phenomenon. Uber launched the first real-time TNC service in San Francisco in 2011, and Lyft and Sidecar launched in 2012. In 2016, an estimated 15 percent of Americans used TNC apps.[46] Lyft and Uber are the most popular TNC apps and operate in most major U.S. cities. From 2013 to 2016, the combined VMTs for Uber and Lyft grew from 30 million to 500 million VMT per month.[47] The growth is particularly noticeable in New York City, where the trips per day for yellow taxis have gradually fallen, while the trips for Uber and Lyft have continued to grow since 2015.[48] Furthermore, the intersection of automation with TNCs has already begun. General Motors invested $500 million for a minority stake in Lyft with the prospect of testing a fleet of self-driving Chevrolet Bolt electric taxis.[49] Uber began piloting self-driving cars in Pittsburgh in 2016.[50]

Microtransit

Microtransit is another form of on-demand, dynamically-routed transit, generally enabled through an internet-based platform that hails multi-passenger vehicles, including SUVs, vans, and shuttle buses. Microtransit emerged in U.S. cities starting in 2012. While microtransit systems are privately operated like TNCs, they often reflect select public transit routes. Current microtransit operations include:

Chariot operates in New York, Austin, Seattle, Columbus, and San Francisco. Via operates in Chicago, New York, and Washington, DC. Los Angeles Metro is developing a curb-to-curb microtransit service as a partnership with the private sector.[51]

Car-sharing

The first car-sharing programs launched in 1994, and the number of programs in the U.S. grew to 22 by 2015, totaling more than 1.5 million car-sharing members.[52] In 2016, General Motors launched a car-share subsidiary called Maven.[53] Daimler similarly created a car-sharing company called car2go. Getaround is a peer-to-peer car-sharing company launched in 2011 that allows individuals to rent out their personal vehicles and currently operates in 10 U.S. cities.

Bike-sharing

Bike-share systems in the U.S. increased from four systems in 2010 to 55 systems in 2016.[54] In 2017 alone, 35 million bike-share trips were taken, a 25 percent increase from 2016.[55]

Mode Shifting and Other Opportunities to Increase Efficiency with Shared Mobility

Increasing efficiency through shared mobility will require looking beyond simple VMT reductions, to focusing on increasing the efficiency of passenger miles traveled – in other words, increasing the occupancy per vehicle. Opportunities to increase efficiency through shared mobility include incentivizing higher-occupancy vehicle travel, integrating public transit with other shared mobility options, and modern carpooling.

A key element to increasing efficiency through shared mobility is incentivizing travelers to use less fuel-intensive means of transportation. Light-duty vehicles are more energy intensive than any other form of passenger vehicle travel.[56] Any shift away from light-duty vehicles to less fuel-intensive or higher-occupancy-per-vehicle forms of travel, such as walking, bicycling, riding on a bus or train, or carpooling, will save energy. Effective approaches to promote mode shifting and shared mobility include pricing and regulatory strategies that increase the costs of single occupancy vehicle travel, land use and smart growth strategies that reduce travel distances, and multimodal strategies that expand travel options.

Continuing to improve and integrate transit options into overall shared mobility planning is paramount to reducing energy consumption. While public transit, by bus or rail, currently accounts for less than 3 percent of passenger trips in the U.S., these modes of transit offer the least energy intensive forms of passenger vehicle travel, averaging about half of the GHG emissions and energy intensity of private car usage on a per-passenger-mile basis.[57,58] Ride-hailing cannot yet compete with mass transit in terms of person-throughput efficiency in limited roadway space; nor can it compete on energy efficiency for passenger-miles traveled. Thus, transit continues to offer significant opportunity for urban cores to reduce overall energy consumption and environmental impact from transportation by shifting passengers away from private cars. To support transit ridership, increasing transit frequency is a significant driver.[59,60] As of 2015, 15 U.S. cities had achieved greater than 20 percent mode share for transit.[61]

The effect of TNCs on transit ridership and overall transportation efficiency is still unclear. While the growth of TNCs is extraordinary, TNCs are still a new industry. As of 2016, about 15 percent of adults in the U.S. had used a TNC app, 51 percent were aware of TNC apps but had not used any, and 33 percent were unaware of any TNCs.[62] TNC ride-hailing currently accounts for no more than one percent of global VMTs.[63] While a January 2018 report by the Shared Use Mobility Center concluded that while, "there is no clear relationship between the level of rush-hour TNC use and longer-term changes in public transit usage," TNCs have the potential to contribute to increased VMTs and energy consumption if their users opt out of less fuel-intensive transportation options.[64] There is concern that TNCs could increase congestion.[65] Effectively integrating TNCs into the transit network is therefore important for mitigating congestion impacts and increasing the overall efficiency of transportation networks.

The global trend toward packaging travel options, often referred to as "Mobility-as-a-Service" (MaaS), will facilitate this integration. MaaS is a combination of public and private transportation services within a locality that enable point-to-point trips with a single payment. Fare integration of multimodal options, and route guidance on multimodal options, are key to MaaS. Mobility marketplaces are mobile applications that allow users to find and pay for a range of transportation options in real time and in one place. This facilitates the use of real-time data and analytics to make energy- and space-efficient travel options viable alternatives to personal vehicles. As mobility platforms designed to efficiently integrate trip-making become more common, they will offer significant opportunities to reduce energy and household expenses. The need for integration of transit and ride-hailing is further underscored by the fact that shared mobility users are likely to use transit as well: a survey conducted for the American Public Transportation Association (APTA) showed that respondents reporting greater use of shared mobility services (e.g., TNC apps, bike-sharing and car-sharing) were more likely than those who did not use any shared mobility to use public transit, own fewer cars, and spend less on transportation overall.[66] Throughout the integration process of MaaS, it will also be critical for public and private partnerships to incorporate access for people with disabilities and comply with the Americans with Disabilities Act.

Despite the transition in consumer behavior to TNCs and other connected vehicle technology, a major advantage that transit systems hold is the capacity to move major crowds in a given timeframe. For example, individually loaded vehicles do not meet the needs of crowds leaving concerts or sporting events, whereas transit is well-suited for demand-heavy events. The growing use of micro-transit, with larger vehicle efficiency, may reduce this inherent advantage of traditional transit.

Treating mobility as a service and designing transportation options with an eye toward providing that service as efficiently as possible can lead to a more effective use of transit. MaaS has the potential to enable the most efficient use of the many transportation options available depending on the user needs. Transit and ride-hailing serve different user needs. Public transit ridership is at its highest during rush-hour, while the majority of TNC trips take place during off-peak periods – on weekends and evenings – when transit is less frequent. [67] For example, the Shared Use Mobility Center found that the highest usage of TNCs occurs at 9 p.m. or 10 p.m. on Saturdays.[68] In an integrated and synchronized system, facilitated through tools like a mobility marketplace, users can more effectively utilize transit where appropriate and ride-hailing for point-to-point purposes.

MaaS is already being implemented in the U.S. To help coordinate among the various mobility options, DOT provides grants through its $8 million Mobility on Demand (MOD) Sandbox program to local partnerships between public and private entities that expand and support multimodal transit services.[69] In 2016, there were 11 MOD partnerships in the U.S.[70] The program aims to improve public transportation through mobility tools and technology to make transportation systems more efficient and accessible.

Other efforts to incentivize higher occupancy vehicle travel, to complement MaaS and the integration of transportation options, include modern carpooling and road pricing:

Modern carpooling

Modern carpooling represents a major opportunity for efficiency improvement. While traditional carpooling has decreased from 20 percent of overall trips in 1980 to around 10 percent today, despite significant expansion of public carpooling incentives such as carpool-only lanes and reduced bridge tolls, TNCs hold the potential to turn this trend around though their pooling services (e.g., Lyft Line and Uber Pool).[71] Modern carpooling in TNC services could even result in new vehicle market opportunities through the higher turnover rates of better-utilized vehicles and demand for new custom-built vehicle classes. The success of modern carpooling depends on many uncertain factors, most notably users' willingness to share rides with strangers in exchange for a discount. Nevertheless, TNCs could expand carpooling beyond its traditional niche in commuting to a wider variety of trips. Matching multiple riders, who would not have otherwise been matched without the aid of the TNC apps, has the potential to reduce the energy intensity of TNC travel and reduce congestion.

Road pricing

Road pricing is one of the most effective approaches for curtailing energy use and can be used to reduce congestion at peak travel times, rein in low occupancy VMT, penalize higher polluting vehicles, or incentivize lower polluting vehicles. Strategies for road pricing include road tolls, congestion pricing, increased gas taxes, mileage-based user fees, pay-as-you-drive insurance, and high occupancy vehicle (HOV) lanes. Revenues from these strategies can be used to bolster other transportation improvements, such as supporting alternate modes of travel like transit.[72] Successful examples of road pricing include:

What is clear from the exponential growth of the shared mobility industry, and promising for transportation planners, is that individuals are willing to change their mobility behavior, quickly and at scale, if they are provided with superior mobility options.

- A University of Maryland paper on road pricing practices highlights Singapore as having the oldest example of urban congestion pricing. Singapore charges an additional fee to cars entering the central business district during peak morning commute hours, resulting in a "73 percent decrease in the use of private cars, a doubling of bus usage, and a 30 percent increase in carpooling."[73]
- The California Air Resources Board has cited road pricing as a key prospective tool to manage VMT and reach air pollution goals.[74]
- A January 2017 CPCS study concluded that a combination of road pricing and ride-hailing implementation could save the City of Toronto 9 billion Canadian dollars, largely with commuter time and fuel savings, through an increase in average vehicle occupancy from 1.08 to 1.20.[75]
- Some communities are also exploring the potential to implement specialized road usage fees that are multiplied significantly when vehicles are empty to penalize vehicular inefficiency and avoid oversupply of vehicle capacity by TNCs.

What is clear from the exponential growth of the shared mobility industry – and promising for transportation planners – is that individuals are willing to change their mobility behavior, quickly and at scale, if they are provided with superior mobility options. While new TNCs are disrupting mobility patterns, it will be critical to integrate these new mobility options with existing transportation systems, like transit. This integration can provide users with synchronized multimodal transportation choices to enable quick and less fuel-intensive service, while reducing congestion and energy consumption.

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COMMUNITY INTEGRATION & DIGITALIZATION

Prioritizing Data Integration

Cities across the country are currently faced with traffic and transit systems that are aging and rarely coordinated with each other. While there are increasingly more opportunities to integrate data-gathering technology into both new and existing infrastructure, finding the funding to do so as well as effectively utilizing the data are constant challenges. According to the DOT, only 28 percent of transit agencies in the U.S. have open data systems that provide transit times to the public. Providing accessible data is a first step in advancing transit integration, while its sparse implementation illustrates the challenges in better utilizing transit infrastructure within American cities.

As mobility options expand, data integration becomes more valuable and necessary. If data streams are integrated, then they could effectively inform policy and influence consumer behavior, enabling the "tuning" of the mobility system for efficiency. Digitization can lead to improved road and transit utilization, and less congestion. There is opportunity to effectively integrate many modes of transport to improve transit utilization. For example, bike-shares join privately-owned bicycles, pedestrians, transit vehicles, and private motor vehicles within road systems that are not typically designed to accommodate all of them at once. At the same time, the proliferation of TNC and car-sharing services has begun to shift how roadways and parking are used within cities. To improve the utilization rate of roads and reduce congestion, all vehicles and modes must have easy access to existing infrastructure. Proper analysis of transportation mode usage data will be critical to inform the shift of balance in mode usage and to make transportation more efficient and equitable.

The composition of American transportation modes has changed dramatically in the last 20 years, with data collection lagging this change and data utilization lagging further still.

The composition of American transportation modes has changed dramatically in the last 20 years, with data collection lagging this change and data utilization lagging further still. Even if there were little further change in the composition of transportation over the next 25 years, which is unlikely, there is still significant progress to be made in digitizing transport infrastructure to enable optimal usage.

Enabled Benefits of Information and Communications Technology

As vehicle types and usage modes expand within U.S. cities, conflicts between vehicles increase and the insight of traditional data-gathering methods becomes more limited. New stakeholders like TNCs, bike-share platforms, and route optimization social networks, such as Waze, are generating more data than ever before, increasing the opportunities for integration.

Better technology platforms could enable more effective use of existing infrastructure. For example, traffic signal timings could be altered to ease congestion. Transit systems could respond to current conditions more dynamically rather than follow the conventional on-peak, off-peak, and weekend schedules. Data-gathering efforts could be expanded as well. Current survey methods can capture vehicle traffic volumes as well as limited data on vehicle speed and type, but technology could significantly expand those capabilities. Data-gathering could be expanded to capture bicycle traffic data, transit volumes, parking utilization, and time-driven usage information, none of which can be captured with current road tube traffic counting systems.

ICT improvements could also open a host of new methods to ensure that transportation networks are efficient, safe, and clean. The DOT issued their Smart City Challenge in 2015 to advance the evolution of ICT technology. Through the Smart City Challenge, cities are exploring applications of ICT to help reduce energy use and emissions, among other benefits. In 2015, 78 cities responded to the Smart City Challenge with plans to "use data, applications, and technology to help people and goods move more quickly, cheaply, and efficiently."[77] The seven finalist cities proposed many approaches that could reduce transportation energy use in addition to streamlining transportation systems. The proposals submitted to the Smart City Challenge demonstrate that city planners have identified the need for more comprehensive data platforms. Columbus, Ohio was the winner of the challenge, but the remaining finalists are pursuing their plans through other initiatives such as the T4A Smart Cities Collaborative.

Several common solutions emerged from the Smart City Challenge proposals, all of which are predicated on increased communication and analysis within traffic flows, including:

- **Mobility marketplaces** are a foundational component of MaaS, as discussed in the Shared Mobility section. Mobility marketplaces can also bring mobility services to populations with low vehicle ownership and limited traditional transit options.
- **Dedicated short-range communication** is short- and medium-range wireless communication that connects vehicles with each other and with infrastructure. Implementation would provide visibility into traffic patterns and improve safety.
- **Unified open data analytics platforms** can enable better use of collected data. Widely available data allows cities to make educated decisions about how to streamline freight and personal travel. The City of Pittsburgh proposed the creation of a Data Utility that would help with internal decision-making, and also allow the development of third party apps to provide users with dynamic information on transportation options.
- **Automated shared use vehicles** are an ambitious technology deployment requiring data-heavy infrastructure.
- Several cities proposed **freight efficiency corridors**, which can increase the speed of goods movement and reduce fuel usage. Denver proposed a corridor that would prioritize truck movement through signalization and provide truck drivers with real-time traffic, routing and parking information. As part of this approach, Denver also would invest in pilot projects to demonstrate the safety and efficiency benefits that come from autonomous heavy-duty and connected freight vehicles.

While improving transportation efficiency is a common theme across smart city planning efforts, other benefits of smart city planning include improved safety and equity as well as increasing customer choice.

Reducing Energy Consumption and Environmental Impact

Future developments in electric and autonomous vehicles provide an opportunity to reduce the average energy consumed during vehicle trips. However, AVs could also increase energy consumption significantly if VMTs 1) increase without improving utilization, 2) are accomplished with traditional internal combustion engine vehicles, or 3) if AV use results in increases in idling or traveling empty vehicles. Future technological developments, including improved EVs and AVs, will need to be enabled by an integrated data platform to reduce energy consumption.

Better infrastructure data usage and integration can improve utilization across all modes of travel. In turn, improving the utilization of vehicles can reduce VMTs, through increased transit usage, increased bicycle usage, improved utilization of ride-hailing or carpooling, or smart adoption and integration of AVs. Reducing VMTs and traffic management solutions, enabled through better data, can further reduce congestion. Further digitization of the infrastructure for AVs and EVs serves to mitigate both the potential threats of disruptive technological change and transport emissions by improving road utilization and enabling a lower energy intensive vehicle fleet mix with more EVs and bicycles, less congestion, and more cost-effective and better-utilized transit systems.

Improving Access to More Efficient Transportation Modes

Cities are increasingly developing programs to incorporate emerging mobility options into communities' existing transportation infrastructure and services. Equity in transportation is limited by both the cost of private vehicles and restricted mass transit coverage. Shared mobility and autonomous vehicles together can bridge the gap between private vehicles and mass transit by providing options for individual transport which do not require the purchase of a vehicle. A variety of pilot projects and initiatives have recently developed targeting low-income households in urban areas, including:

- The City of Los Angeles is expanding the reach of its car-sharing and TNC programs. The city recently implemented a car-sharing pilot program as part of its Sustainable City pLAn to bring 100 EVs to some of the lowest-income communities in Central LA.[78,79]
- In Chicago, the Shared Use Mobility Center has partnered with Getaround to create a pilot peer-to-peer car-sharing network in low-income communities.[80] The program has registered more than 5,000 residents who share 75 vehicles on an as-needed basis, indicating keen interest in alternatives to personal vehicle ownership in these communities.[81]
- The Better Bike Share Partnership is bringing bike sharing to underserved communities to make bicycles a viable option for travel. In its pilot city of Philadelphia, Better Bike Share funded the construction of 20 bike stations in underserved communities. Better Bike Share also has awarded grants to bike-share programs in several cities across the U.S., including Boston, Brooklyn and Washington, DC.[82]
- Veyo is one of multiple companies that provides on-demand rideshare services for medical transport to underserved populations.[83]

When designing for better access to a multimodal transportation system, the policies governing the development process vary by transportation mode and require coordination. For example, there is a difference between the policies that impact new build versus existing built environments. Many cities require new buildings to provide parking spaces and adopt single use zoning, which may be counter to public transit initiatives. Similarly, existing infrastructure may limit the opportunity for community planners to accommodate the range of transportation options they would like to implement.

Approaching urban design from a holistic perspective is a significant opportunity for urban planners to implement strategies that provide systemic energy and overall welfare benefits. This is particularly the case for urban sprawl, where long distances and sparse infrastructure motivate individuals to adopt single-passenger travel to commute between home and work. Effective land use can play a critical role in reducing passenger VMTs. Land use policies can help to reduce commute times and improve access to less energy-intensive transportation modes.

Often, commuters living in suburbs live far from their workplaces and have limited access to convenient and quick transit. In 2016, over 76 percent of Americans drove alone to work every day.[84] Currently, a commuter in New York spends an average of nearly 90 hours in traffic annually.[85] Improved land use and incentivizing more residents to live closer to the core of cities along with increased access to transit could significantly reduce single-passenger miles traveled, thereby reducing congestion and energy consumption.

Congestion not only impacts vehicle energy consumption, but it also stresses the transportation system by accelerating the deterioration of roads. Strategically locating homes, workplaces, and essential services like grocery stores within convenient proximity to one another has the potential to reduce road use, further reducing energy spent on road maintenance.

Further research into quantifying the impacts of effective land use and the calculation of energy expenditures over longer timeframes could justify investments in improved urban planning to reduce transportation system energy consumption. For example, government agencies could measure the total energy of “vehicle miles built,” including both the fuel expended in a given system (e.g., through direct use, maintenance, and deadheading) plus the embodied energy of the system itself.

Improving Safety

As motor vehicle accidents were the cause of death for 20,295 people between the ages of one and 44 in 2016 in the U.S., better understanding road usage represents a significant opportunity to improve safety.[86] Within cities, the interactive impacts of transportation modes and vehicle speeds significantly affect safety. This is an area where improvements to road and network design could have significant impacts. Given better data, roadway infrastructure can be redesigned to reduce vehicle speeds, improve the safety of pedestrians and cyclists, and reduce congestion.

Agencies and organizations including the Federal Highway Administration and the American Association of State Highway and Transportation Officials have released specifications and guidelines around designing roadways for multimodal use.[87] Effectively implementing these specifications requires an understanding both of road use by all types of users and of unintended consequences. More consistent data collection would permit more granular analysis of road use and would provide data needed to model the impacts of roadway alterations. This data approach would reduce the time and cost of roadway improvement projects, as well as make it easier to quickly identify and correct traffic issues. Deploying better monitoring tools could have a dramatic impact on city traffic safety, especially when paired with Vision Zero plans. Championed by local leaders, Vison Zero is a series of city infrastructure plans and challenges with the goal of reaching zero traffic deaths.[88]

Increasing Consumer Choice

ICT can improve consumer mobility options in many ways. Having access to information based on real-time data and customized to the user will make travel more convenient and enjoyable, thereby increasing the appeal of more energy efficient transportation options to more users. Cities can work with private partners to provide mobility marketplaces to help travelers find the best route at any time of the day. Mobility marketplaces may include information on delays, congestion, weather, incentivized pricing (including pricing based on time of use), and other factors that impact the user experience. The platform could allow commuters to use a single payment scheme from their starting point to their destination regardless of whether they use a shared bike, train, bus, and/or shared vehicle. Additional conveniences to increase consumer choice may include providing services such as free WiFi on public systems or providing freight lockers for package deliveries and fresh foods at transit stations. The increased options presented to users, through integrated planning tools connected with a single payment system and/or increased access to goods and services, makes traveling much more convenient.

There are an increasing number of companies managing the transportation of goods and services to coordinate trips by developing the most efficient routes and paths. Automakers are developing more seamless experiences to complement their customers' lifestyles by leveraging digitalization technologies to enhance the overall experience interacting with the automobile or with the brand. Part of the value created through connected data, via the vehicle or from users' devices, is the ability to deliver services and goods at a preferred location with a focus on convenience. Some examples include delivery of fuel, groceries, and supplies directly to a parked vehicle, home, or work location. Further potential with the advent of drone delivery technologies may eliminate the need for trips taken for minor food and supply items.

Reducing commute time to workplaces is a significant opportunity to reduce energy use through increased consumer choice. For example, companies can allow employees to work from home or use satellite offices that are more local to residential neighborhoods. Cities can also create corridors between affordable neighborhoods and workplace hubs that connect the two locations with efficient public transportation. Furthermore, cities can work with employers in public-private partnerships to provide transit benefit plans to commuters to encourage the use of public transit and other shared mobility modes.

Challenges to Community Integration of Connected Transportation

To benefit from the application of ICT, the overarching challenge is data collection, analysis, and management. Finding solutions to this data issue will be critical to effective implementation of connected transportation. Some cities, such as Austin with its "Data Rodeo," have already developed an open data platform that facilitates the development of applications using disparate data sources.[89]

As data management capabilities continue to grow, there is a need to determine how best to manage, protect, and anonymize user data. Consumer choice will rely heavily on applications that leverage high quality data available to both public and private goods and service providers. Communities will need to consider how they will collect, analyze, and provide the data, including protecting the privacy rights of the data sources. This includes determining how to engage third parties to handle data management while still maintaining data privacy and security, what the appropriate level of data anonymization is, how much user data should be shared, and the level of responsibility of government stakeholders to protect user data.

Cities could benefit from developing or following existing models for a data governance plan, such as the one released by the Federal Highway Administration in 2015. This plan includes metrics for data quality, identifies individuals responsible for this oversight, tests for reliability and interoperability, and establishes processes for archiving or purging inactive data. If a community is working with private sector partners, it is especially important to establish policies that set bounds on their data rights. Policies should also outline what data can be made publicly available, in which format, and the frequency by which this information is updated.

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