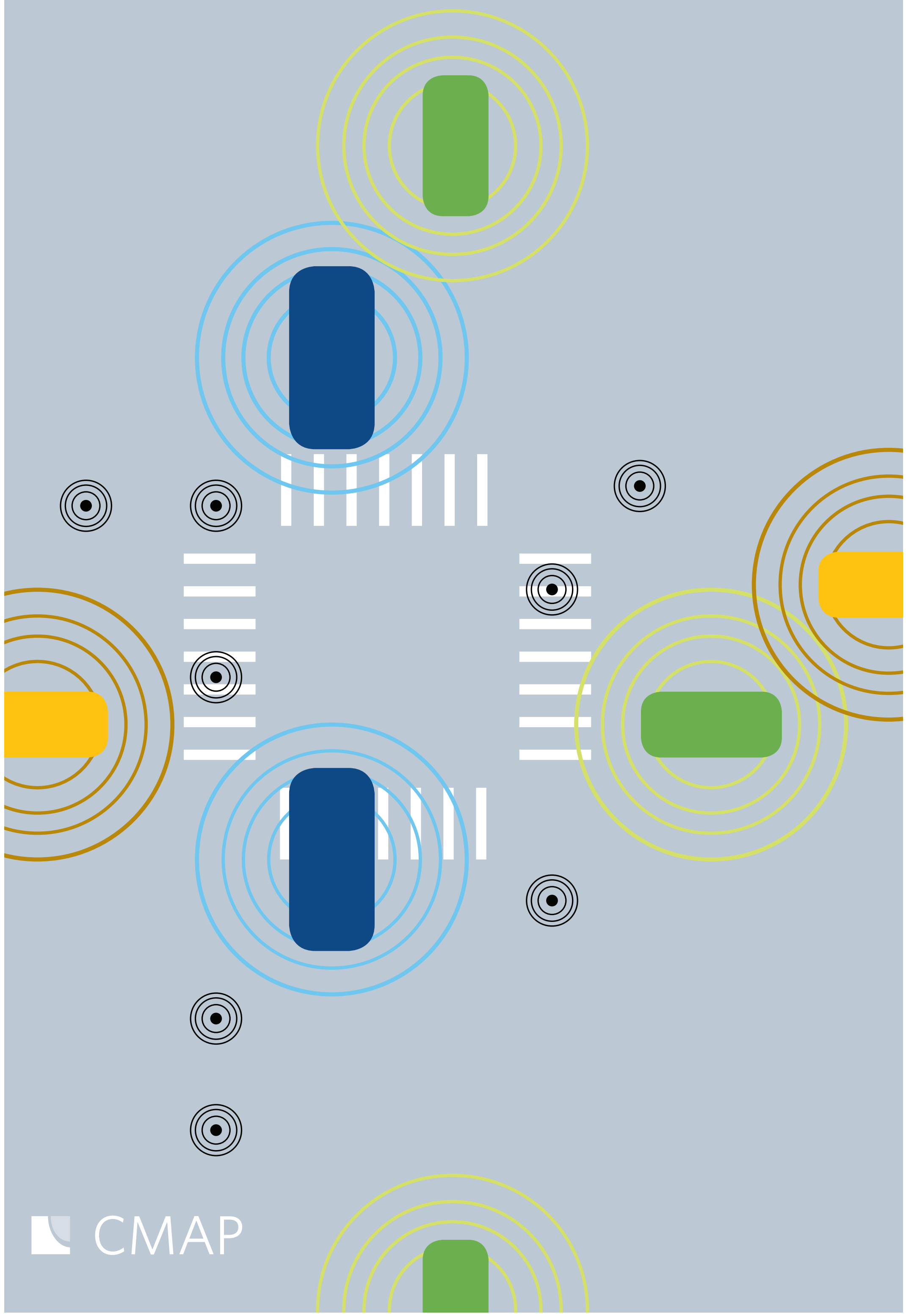
CHICAGO METROPOLITAN AGENCY FOR PLANNING | **ON TO 2050** STRATEGY PAPER

Transportation Technology



CMAP

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Introduction

As part of the development of ON TO 2050, CMAP staff is in the process of developing a series of strategy papers -- reviewing current policies, emerging issues, and potential future directions -- on various issues. This strategy paper explores the way that emerging transportation technologies may affect the future of the Chicago region.

From canals to railroads to highways, transportation technology has been a major force shaping land use and driving the economy of the Chicago region. By 2050, automated vehicles and other emerging technologies are poised to have transformational impacts of similar magnitude. This strategy paper explores recent developments and possible future impacts of emerging technologies with the potential to affect land use, travel patterns, economic activity, governance and quality of life, including:

- Connected vehicles & smart infrastructure
- Automated vehicles
- Shared mobility
- Transportation data and goods delivery
- Alternative energy

These technologies present both a remarkable opportunity and a challenge for regional planning. The pace and disruptive nature of technological change makes it difficult, if not impossible, to predict what technologies will be commonplace by 2050. And yet, infrastructure investments the region makes in the next few years will be in operation for many decades.[1] By making strategic investments and policy interventions, the region may be able to shape the development of emerging technologies and better position the Chicago region to achieve its goals for economic vitality and improved quality of life for all. Decisions about investments and policies will need to be coordinated across many levels of government, and engage the private sector, civic leaders, and residents. This strategy paper identifies actions CMAP and its partners can take to shape the development of emerging technologies and advance regional priorities.

[1] For example, most Metra cars were built in the 1980s, before customers needed Wi-Fi and charging stations, and before modern communications and signal technology allowed better tracking and movement of trains.

Research process

The Emerging Transportation Technology strategy paper focuses on technologies that are likely to have a significant impact on the region by 2050, but which have substantial uncertainties about when or if they will reach mass adoption. This paper is related to three other ON TO 2050 strategy papers - Highway Operations, Energy, and Transit Modernization - which all address emerging technologies to some extent, but which focus primarily on existing technologies and shorter term implementation and impacts. A series of memos on the regional economy (innovation, human capital, economic development) will assess both near and long term impacts of technological change on the region's economy. Because this strategy paper focuses on emerging technologies across modes, it will pay careful attention to what key uncertainties may influence the impact of the technology on CMAP priorities such as land use patterns, mobility, and inclusive growth.

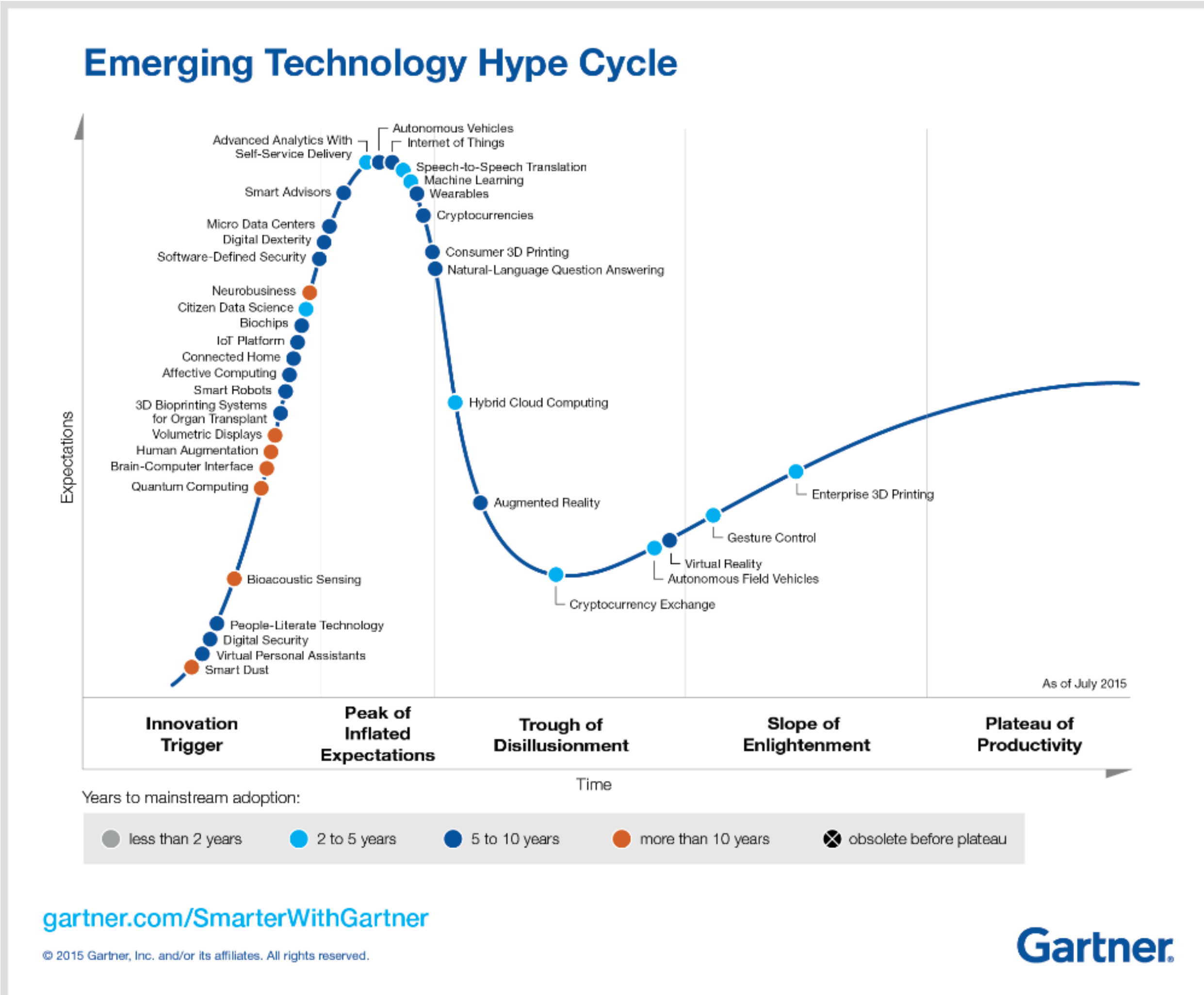
During the research process for this paper, CMAP contracted Cambridge Systematics to conduct a literature review about emerging technologies and interview leaders in private industry and academia on their thoughts about how these technologies might evolve in the coming decades. A list of interviewees is available in the Appendix. CMAP used the Cambridge research to inform staff analysis of the key actions it and other partners can take to harness technological innovations to improve mobility, maintain and modernize the transportation network, and meet land use and livability goals for the Chicago region.

Emerging transportation technologies

This document discusses the many uncertainties posed by emerging technologies, including when they might be broadly adopted, when industry standards will be formed, or what transportation, land use, and economic impacts might occur. Understanding where technologies fall on the "hype cycle" illustrates this problem. The hype cycle tracks changes in expectations and adoption of a technology over time. Technologies move from early proof of concept through the "Peak of Inflated Expectations" where excitement about the technology is fueled by media coverage and publicity. In the "Trough of Disillusionment," early experiments and pilots fail to deliver on heightened expectations. If technologies can overcome these hurdles and demonstrate value to consumers, they can reach the "Plateau of Productivity" and begin to move towards mass production and adoption.

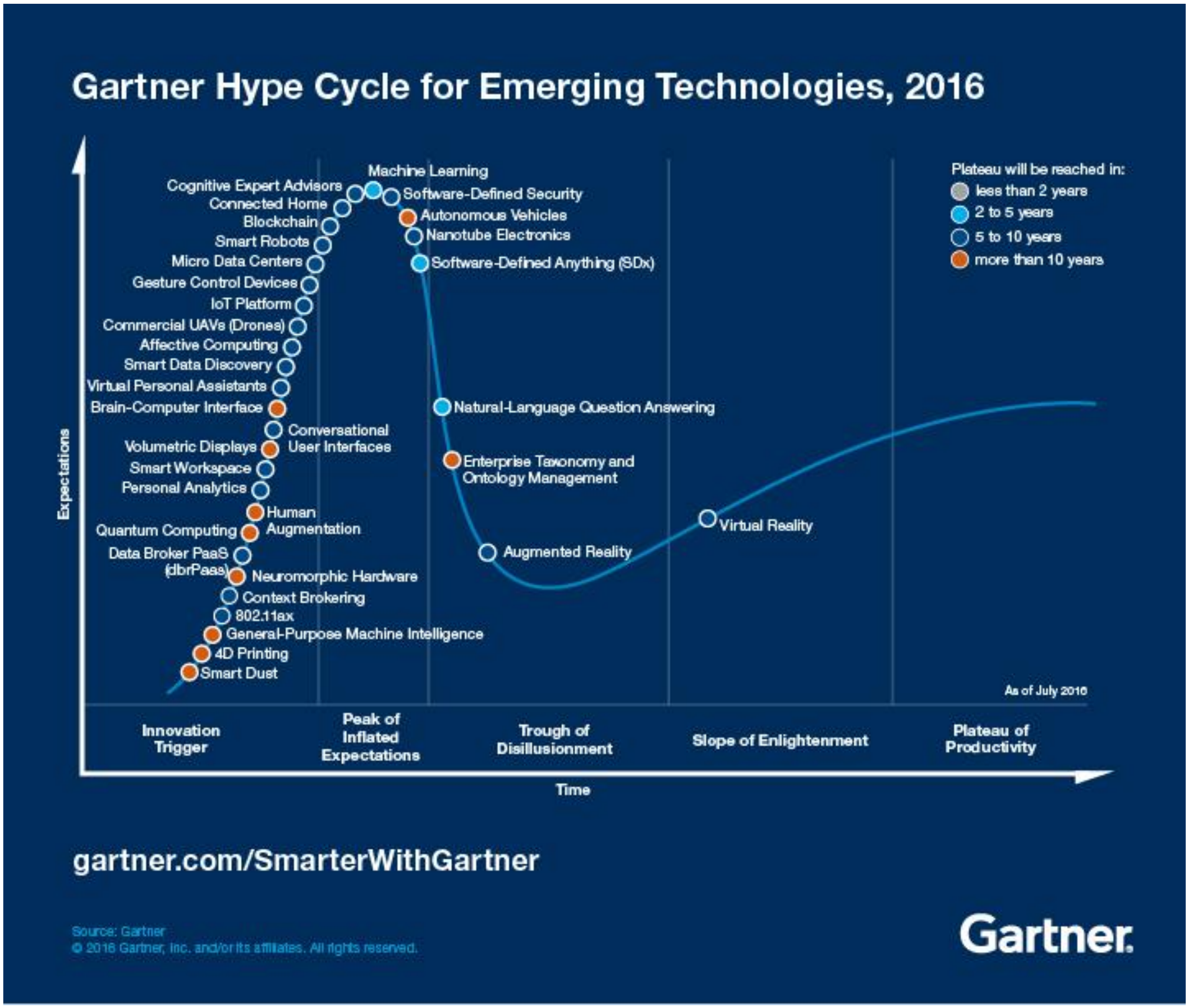
Figures 1 and **2** display the Hype Cycles for 2015 and 2016 respectively. A number of transportation technologies appear in these diagrams, most notably autonomous vehicles, which Gartner places near the peak of inflated expectations.

Figure 1. Gartner Emerging Technology Hype Cycle, 2015.



Source: Gartner, 2015.

Figure 2. Gartner Emerging Technologies Hype Cycle, 2016.



Source: Gartner, 2016

Understanding hype cycles can also help agencies avoid unrealistic expectations of technology and make careful, proactive, and measured investments and policy decisions. For example, autonomous vehicles are now at the "peak of inflated expectations," and actual implementation may lag today's expectations. There are still many barriers, such as an inability to consistently sense bicyclists or animals. The industry may take some time to overcome these barriers, but public and private researchers are making advancements and investments in the technology. Understanding that true implementation of this technology may be 10 years out, rather than just a few years, aids planning and policy decisions.

The following outlines potential impacts of five key areas of emerging transportation technology: connected vehicles and smart infrastructure, automated (and connected) vehicles, shared mobility, transportation and goods movement data, and alternative energy. Each section addresses potential transportation, land use, and inclusive growth outcomes, with a focus on infrastructure and the built environment, as well as outlining uncertainties that may affect policy and planning decisions.

Connected vehicles and smart infrastructure

Connected vehicles (CVs) and "smart" infrastructure interact with the environment and one another to provide greater safety, comfort, and entertainment. With the appropriate communication network in place, vehicles with on-board communications (such as Dedicated Short-Range Communications or DSRC, cellular, Wi-Fi, satellite, Bluetooth, etc.), can send vehicle information such as location and speed to roadside units. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) technology enables automated vehicle operation, including radar-based active braking and vehicle-control algorithms to improve safety and fuel efficiency, collision mitigation systems that detect stopped or slowed vehicles far down the road to alert the driver and apply brakes when needed.

Mainstream adoption of connected vehicles and smart infrastructure has the potential to reduce congestion and improve roadway safety by greatly enhancing the quantity, quality, and velocity of available data. Gartner predicts that by 2020, more than 250 million vehicles will be connected globally.[2] Most long-range scenarios on vehicle trends expect the population of equipped vehicles to exceed 90 percent by 2050.[3] A key area of uncertainty around connected vehicles and smart infrastructure development is what communications technology will form the backbone of the system. Either of two competing wireless network types could support vehicular communication: DSRC and 5G. DSRC technology is more developed, tested, and commercially available, but 5G may eventually be able to provide the basic functions offered by DSRC as well as additional in-car features that passengers want. In December of 2016, National Highway and Traffic Safety Administration (NHTSA) published their Notice of Proposed Rulemaking (NPRM),[4] which would require manufacturers to install DSRC radios into new vehicles, starting in about 2020. The communications infrastructure and data processing capacity necessary for providing connected vehicle features pose privacy, data security, and physical safety vulnerabilities of connected vehicle computer systems.
Research has indicated a range of potential improvements that largely depend on the market penetration of these technologies: connected vehicles could improve roadway capacity by 20 percent with relatively low market penetration, and at 33 percent or more of the market,

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[2] Ninan, Simon, Bharath Gangula, Matthias von Alten and Brenna Sniderman "Who Owns the Road? The IoT-Connected Car of Today—and Tomorrow," Deloitte Insights, August 18, 2015, https://dupress.deloitte.com/dup-us-en/focus/internet-of-things/iot-in-automotive-industry.html.

[3] AASHTO, "National Connected Vehicle Field Infrastructure Footprint Analysis," Publication No. FHWA-JPO-14-125, June 2014.

[4] NHTSA, "U.S. DOT Advances Deployment of Connected Vehicle Technology to Prevent Hundreds of Thousands of Crashes," December 15, 2016. https://www.nhtsa.gov/press-releases/us-dot-advances-deployment-connected-vehicle-technology-prevent-hundreds-thousands.

connected vehicles would significantly reduce delays at urban intersections.[5] [6] Capacity improvements present an opportunity to not only improve congestion, but also reallocate roadway right of way for transit, active transportation, and other purposes. Connected vehicle warning systems and autonomous emergency braking could reduce fatalities by as much as 57 percent.[7] V2V and V2I technology can reduce fuel consumption and provide additional amenities to passengers. Traffic-light-to-vehicle communication systems could help drivers avoid braking and accelerating maneuvers and reduce fuel consumption 8 percent to 22 percent.[8] Cyclists can also take advantage of connected infrastructure technology, receiving information about road conditions and safety en route, as well as alerting nearby cars, trucks, and transit vehicles to their presence.

Real-time roadway conditions, congestion levels, travel times, and incident-related information of roadway users can be used to augment existing Transportation Systems Management & Operations strategies (TSM&O). Although public agencies and private firms already generate and use large quantities of data about the transportation system, more real-time data provided by CVs could provide transportation operators with more timely and accurate performance data to improve emergency responder dispatch, monitor vehicle and infrastructure condition, and manage congestion. In addition to safety and capacity benefits, electronically coupling heavy trucks using V2V communications allows trucks to accelerate and brake together and operate at closer distances to form a platoon.

Bus transit riders on routes with authorized transit signal priority (TSP) at key intersections would benefit from faster, more reliable service that could make transit a more attractive travel option. Additional real-time data about transit operation, including travel times and arrival information can improve customer experience. These technologies could enable more extensive vehicle infotainment systems for transit riders and auto passengers, such as Internet radio, video streaming, web browsing, connected media, and more. Increased mobile-data

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[5] Ni, Daiheng, Jia Li, Steven Andrews, and Haizhong Wang, "A methodology to Estimate Capacity Impact due to Connected Vehicle Technology", International Journal of Vehicular Technology Vol 2012, September 7, 2011, http://www.itsknowledgeresources.its.dot.gov/ITS/benecost.nsf/0/70212CAA6C95BA5D85257B510055CD6E?OpenDocument&Query=Home.

[6] Priemer, Christian and Bernhard Friedrich, "A Decentralized Adaptive Traffic Signal Control Using V2I Communication Data"' Proceedings of the 12th International IEEE Conference on Intelligent Transportation Systems, October 2009, http://www.itsknowledgeresources.its.dot.gov/ITS/benecost.nsf/0/844389AFAC48AA4B85257EEB00642F90?OpenDocument.

[7] Doecke and Anderson, "Crash reduction potential of connected vehicles in South Australia", Center for Automotive Safety Research at the University of Adelaide, February 2013, http://www.itsknowledgeresources.its.dot.gov/ITS/benecost.nsf/ID/458522B76F5CF56885257D890073621E?OpenDocument&Query=Home.

[8] Tielert, T, M. Killat, H. Hartenstein, et al. "The Impact of Traffic-Light-to-Vehicle Communication on Fuel Consumption and Emissions http://www.itsknowledgeresources.its.dot.gov/ITS/benecost.nsf/ID/0DBE1DFA0628439685257EF30061BF96?OpenDocument&Query=Home.

consumption has potential for additional revenue for transit agencies, like how airlines and airports charge a fee for, or provide sponsored access to, in-flight entertainment.

Table 1. Examples of Intelligent Transportation System Technology applications in connected vehicles.

ITS Technology	Traditional/Existing Solutions	C/AV Potential
Dynamic Message Systems	Electronic signs provide real-time travel information to motorists.	Motorists can directly receive information inside vehicle, potentially rendering signs obsolete.
Travel Time System	In-pavement or roadside-mounted point-to-point sensors read a unique signal and estimate travel time. Existing probe data systems (primarily using Bluetooth technology) provide travel time data to both agencies and private customers.	DSRC can, in the short term, increase the density of probe data and potentially transition to replace current methods. Benefit can be extended to motorcyclists and bicyclists. This is effective even with low market penetration.
Signal Coordination Study	Pre-timed signals allow traffic to flow freely through a corridor based on a manual field survey.	Field survey data can be automatically collected through DSRC. This requires medium to high penetration for data accuracy.
Intersection Monitoring and Detection	This technology converts signals from pre-timed to actuated logic, where signals will skip approaches when sensors detect no vehicle and the pedestrian push button is not active.	Mitigate negative impacts on motorcyclists and bicyclists who are not detected by complementing sensor data with DSRC signal data.
Adaptive Traffic Signal Technologies	These technologies allow signal logic to change based on traffic condition information collected by sensors.	Traffic conditions data can be collected through DSRC instead of sensors. This would require medium to high market penetration for data accuracy.
Traffic Signal Interconnect	The interconnect ties traffic signals to a common clock for executing pre-timed plans via fiber optics or wireless communication.	DSRC can serve as the wireless communication medium for intersections that are within a 400 meter line of sight of each other.
Close Circuit Television (CCTV) Cameras	CCTV cameras provide real-time visual monitoring of a road facility requiring a high-capacity communications network.	Existing CCTV would help CV deployment, as the existing backhaul communications can be utilized.
Transit Signal Priority (TSP) and emergency vehicle preemption	Transit or emergency vehicle requests extended green to clear intersection or requests overrides of signal timing to provide green lights.	DSRC can serve as a wireless communication medium and provide a response to the vehicle advising whether priority has been granted.
Pedestrian Push Buttons and Countdown Signals	Pedestrians request walk signals (particularly for adaptive traffic signals) and are provided with a visual countdown of remaining crossing time left.	Disabled or senior pedestrians can request extended green time through a DSRC-enabled smartphone.

Source: Adapted from Connected/Automated Vehicle Impacts on Transportation Planning: Primer, prepared by Cambridge Systematics for US DOT Joint Program Office, 2016

Many decisions about communications and security standards will be made at the federal level, but implementers in the Chicago region will need to decide where and when to implement connected infrastructure technology. Investment decisions will be complex, as connected infrastructure could reduce some maintenance costs, but may also increase capital costs to develop and maintain more complicated communications and data processing infrastructure, or replace early investments as standards evolve. Investments in V2V technology are likely to be driven by the private sector and can be more easily upgraded as the fleet turns over, but may not provide the extensive congestion mitigation, transit priority, and incidence response functions that V2I infrastructure can. The Chicago region is already moving forward with some smart infrastructure projects. The "smart corridor" project on the Illinois Jane Addams Memorial Tollway will use sensors planted in the roadway and gantries to inform overhead digital signs, which can be used to update advisory speed limits based on traffic flows, alert drivers of congestion or collisions, or indicate lane closures as needed.

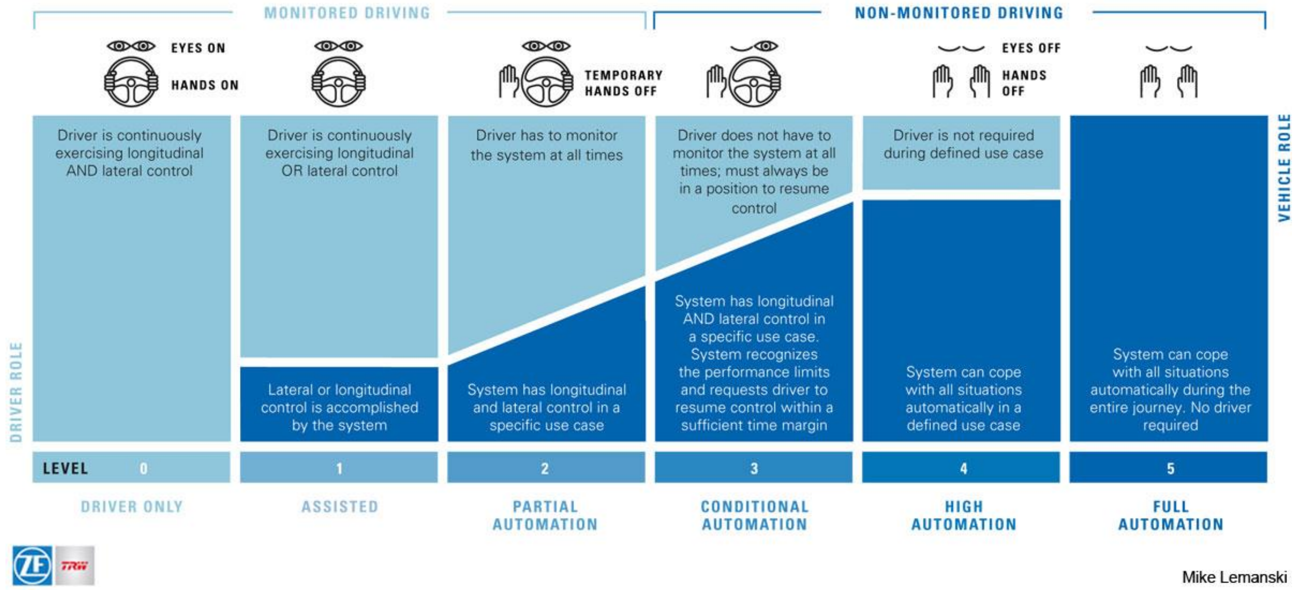
Automated vehicles

In recent years, few emerging transportation technologies have captured as much public and policymaker attention as automated vehicles. Automated vehicles make intelligent decisions regarding a vehicle's direction, speed and interaction with other road users (i.e., cyclists and pedestrians) through the utilization of global positioning system (GPS), radar and light detection and ranging (LIDAR) technology. Although commonly referred to as driverless, self-driving, or autonomous, the federal government and policy experts in the field use the term automated because these technologies exist on a spectrum with varying levels of human and machine control.

Fully automated vehicles (AVs) are capable of sensing their environment and navigating without human input, meaning that passengers can sleep, work, or engage in other activities on their commute. While fully automated vehicles are likely decades away from mass adoption, semi-autonomous features such as adaptive cruise control, parking assist systems, lane departure warning systems, lane keeping systems, and autonomous braking are becoming increasingly prevalent in new car models. The Society of Automotive Engineers' (SAE) vehicle standards committee has defined six levels of driving automation to help industry and consumers understand how vehicle automation can progress safely, as shown in **Figure 4.**[9] Currently, most commercially available vehicle automation features fall into SAE Levels 1 and 2.

[9] Lemansky, Mike "Autonomous cars must progress through these 6 levels of automation." ZF-TRW, 2016 http://safety.trw.com/autonomous-cars-must-progress-through-these-6-levels-of-automation/0104/.

Figure 3. Six levels of vehicle automation.



Source: ZF-TRW, 2016.

Over 30 automobile manufacturers are currently trying to develop a fully autonomous passenger vehicle. Several industry leaders are designing autonomous commercial vehicles, such as driverless shuttles, buses, and trucks. Driverless transit initiatives have taken off in recent years, with small- and large-scale demonstrations across the globe in Europe, Asia, and the United States. In the United States, the NHTSA will regulate automated vehicle performance and set standards that manufacturers must meet before selling vehicles.[10] The range among predictions for mass adoption of fully autonomous vehicles is wide, with most industry experts projecting that they will be available for purchase between the mid-2020s and early 2030s.[11]

The rate of technology adoption will depend on a number of factors, including the price of remote sensing technology, the adoption of V2V and V2I technology, and customer preferences. Currently, the LIDAR systems used on the Google AVs cost approximately $70,000 for the equipment alone. A J.D. Power and Associates survey reveals that only 20 percent of people would purchase an AV if it increases the purchase price of the vehicle by $3,000. These market dynamics may make fleet purchasing of AVs by mobility service companies a more financially viable model. The fleet ownership model may have the effect of increasing autonomous vehicle adoption more rapidly than individual purchase, as it often takes decades for commercially-available technologies (from airbags to automatic transmissions to in-vehicle navigation

[10] National Highway Traffic Safety Administration. Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety, September 2016.

[11] Kessler, Sarah, "A timeline of when self-driving cars will be on the road, according to the people making them" Quartz, March 29, 2107, https://qz.com/943899/a-timeline-of-when-self-driving-cars-will-be-on-the-road-according-to-the-people-making-them/.

systems) to go from premium feature on new cars to ubiquitous feature on every car on the road.[12]

Road-based transportation modes (cars, buses, and trucks) are likely to be more significantly impacted by automation than rail-based passenger and freight transportation, both because many of these technologies are already available for rail and because the economics of rail transportation are very different from road-based transportation. For example, the rail industry is currently in the process of implementing federally-mandated Positive Train Control, which provides automated safeguards to prevent crashes or derailments. Fully automated train technology has been available for decades, but application has been mostly limited to new elevated or closed systems, like airports and elevated or subway systems. Rail automation projects also involve substantial capital-intensive retrofits of existing infrastructure. In comparison to road operation, labor costs are a smaller fraction of rail transportation budgets, limiting the potential cost savings of automated operation.

Adoption of fully autonomous vehicle technology may be quicker in freight vehicles than in passenger vehicles, because labor represents nearly 40 percent of an average trucking firm's costs.[13] Adoption may be particularly swift in controlled environments such as intermodal ports. The container cranes at the Port of Rotterdam are unmanned and practically fully automated, and more intermodal automation has been proposed in facilities in the US.[14] [15] These innovations could allow continuous operation of intermodal facilities with minimal staff. McKinsey & Company projects that by 2025, at least one-third of new heavy trucks will be semi-autonomous, eliminating the need for a full-time driver.[16] In the short-term, semi-automated and fully automated vehicles, shared fleets, and transit will need to operate alongside traditional vehicles.

A vehicle fleet with a large number of autonomous vehicles has the potential to dramatically decrease motor vehicle crashes and fatalities and increase the capacity of roadways. In the

[12] Litman, Todd, "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning," Victoria Transport Policy Institute, September 8, 2017, http://www.vtpi.org/avip.pdf.

[13] W Ford Torrey, IV and Dan Murray, "An Analysis of the Operational Costs of Trucking: 2016 Update" American Transportation Research Institute, September 2016, http://atri-online.org/wp-content/uploads/2016/10/ATRI-Operational-Costs-of-Trucking-2016-09-2016.pdf.

[14] "The Robot is Coming" Port of Rotterdam, Accessed July 2017, https://www.portofrotterdam.com/en/cargo-industry/50-years-of-containers/the-robot-is-coming.

[15] Uranga, Rachel, "Port of L.A.'s automated terminal: Future of commerce or blue-collar job-killer?" Press-Telegram, March 18, 2017, updated September 1, 2017, http://www.presstelegram.com/business/20170318/port-of-las-automated-terminal-future-of-commerce-or-blue-collar-job-killer.

[16] O'Brien, Chris, "One-third of all long haul trucks to be semi-autonomous by 2025" trucks.com, September 12, 2016, https://www.trucks.com/2016/09/12/one-third-trucks-autonomous-2025/.

Chicago region in 2014, 366 people were killed and 41,858[17] injured in motor vehicle crashes, and motor vehicles were the 13th most common cause of death nationwide. Driver actions were the critical reason for 94 percent of U.S. crashes.[18] At high rates of technology adoption, fully automated vehicles are expected to improve roadway capacity by between 15 percent and 100 percent.[19] Connected autonomous trucks hold promise for achieving new efficiencies in productivity of goods distribution. Autonomous freight vehicles traveling in platoons can travel farther with lower fueling and labor costs, meaning more consumers can be serviced within a one-day range of a distribution center, critical in dense urban areas where demand for distribution space outpaces supply. In less dense parts of the region that are more difficult to serve with traditional bus and rail transit service, automated public transit or private shuttle services could provide faster and more frequent "last mile" connections to high-frequency mass transit.

Although there is great promise of significant benefits in efficiency, safety, and personal mobility from AVs there are also substantial land use and development impacts that may arise. Much of the speculation on the potential effects of AVs hypothesizes two potential paths: one in which the technology encourages more low-density, auto-oriented development patterns and increased vehicle miles traveled, and another in which the technology enables a reduction in car ownership and facilitates more dense, walkable development patterns and increased use of transit and active transportation. The transportation investment, land use, and pricing decisions that the region's stakeholders make can help pave the way for the preferred path of AVs.

The reasoning behind the first path is that as the cost and inconvenience of low occupancy vehicle travel goes down with automation, people may choose to live in places that would previously have required too much unproductive time behind the wheel of a car. People and employers could move to less dense parts of the region to take advantage of lower land prices and more open space while still having convenient access to all their daily needs. With less demand, some existing denser communities may see declines in population and residential property values. Substantial development on agricultural land and in natural areas could occur, requiring new infrastructure, including roads, utilities, and drinking water, sewer, and stormwater systems. Low occupancy vehicles and zero-passenger trips in particular could more than offset increases in roadway capacity gained from connected autonomous vehicles and increase congestion on routes into major activity centers. Public transit, which has long

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[17]Illinois Department of Transportation Division of Traffic Safety, "2014 Illinois Crash Facts and Statistics," http://www.idot.illinois.gov/Assets/uploads/files/Transportation-System/Resources/Safety/Crash-Reports/crash-facts/2014%20CF.pdf.

[18]US Department of Transportation, Traffic Safety Facts, "Critical reasons for crashes investigated in the national motor vehicle crash causation survey," February 2015, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115.

[19]Bierstedt, Jane, Aaron Gooze, Chris Gray, Josh Peterman, Leon Raykin and Jerry Walters " Effects of next-generation vehicles on travel demand and highway capacity," January 2014, http://orfe.princeton.edu/~alaink/Papers/FP_NextGenVehicleWhitePaper012414.pdf.

provided productivity advantages to passengers, may struggle to retain riders who can afford private autonomous options that offer faster, more comfortable, door-to-door, on-demand travel. Bus service on more congested streets may become slower and less reliable, making it an even less attractive alternative. Low frequency routes through less dense neighborhoods would likely experience particularly steep declines in ridership as new autonomous options become available. Lower ridership may lead to these bus routes being cut entirely reinforcing these areas' dependence on low occupancy vehicles.

The rationale for the second path is that if AVs are mostly deployed as higher-occupancy vehicles, they may enable municipalities to support their goals for increased transit ridership, walkability, and transit-oriented development. Availability of on-demand AVs could encourage a reduction in car ownership rates. As households own one or fewer cars, they are more likely to avail themselves of multiple options, including transit, walking, and biking, and importantly, less car ownership makes parking availability less of a factor in choosing where to live. The ability of automated vehicles to drop off passengers and park themselves in more compact and remote locations could open up land in commercial areas and activity centers for infill development. In residential areas, it could free up garage and driveway space for more productive or recreational use, and in neighborhoods where on-street parking is heavily utilized, it could enable new streetscape features such as bike lanes, bus lanes, wider sidewalks, or planted medians. The cost of development in denser areas could also decrease if developers no longer need to factor in the cost of parking spaces into construction costs. Some researchers even speculate that since risk-averse automated vehicles will always stop for pedestrians, it will be easier to navigate dense urban neighborhoods on foot than in a vehicle, enabling more pedestrian-oriented development in these areas.[20]

In both of these potential futures, AVs present equity challenges. If use of AVs are cost prohibitive for lower income households, the potential for public transit cuts is problematic not just from a congestion, land use, or emissions standpoint, but from an equity standpoint as well. Transit agencies will struggle to provide sufficient service to these populations with a smaller revenue base. In other words, a downward spiral of ridership loss and service cuts could be triggered, leaving fewer routes with lower frequencies as the only option for poorer residents, while middle and high income residents get exclusive use of AVs.

While much of the conversation about AVs focuses on these two disparate futures, it is likely that the impacts of AVs will be dependent on the cost and convenience of low- and zero-occupancy autonomous vehicle travel, which will vary substantially across the country and even within regions. Dense urban neighborhoods may see car ownership decline and substantial reallocation of road space, while suburban areas may see expanding auto-oriented development patterns. Policies affecting the cost and convenience of low occupancy vehicle travel will need to be addressed at the local and regional scale.

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[20] Hurley, Karinna, "How pedestrians will defeat autonomous vehicles" Scientific American, March 21, 2017, https://www.scientificamerican.com/article/how-pedestrians-will-defeat-autonomous-vehicles/.

Cities, states, and regions across the country are approaching automated vehicle technologies with varying degrees of enthusiasm and skepticism. Since 2012, at least 41 states and DC have considered legislation related to autonomous vehicles. Nineteen states have passed legislation, and governors in three other states have issued executive orders related to autonomous vehicles.[21] Common provisions include exempting platooning vehicles from minimum following distance requirements, authorizing automated vehicles to operate on public roads, establishing safety and liability coverage requirements for automated vehicle operation, preempting local units of government from regulating automated vehicles, and establishing advisory boards to further consider automated vehicle regulations. Five bills were proposed in Illinois in 2017, but none have yet been enacted. The Illinois House and Senate both passed a bill that, if signed by the governor, would prevent a unit of local government from prohibiting the use of autonomous vehicles on its roadways.[22]

In October 2015, the Contra Costa Transportation Authority in northern California signed an agreement with EasyMile for a two-year test of two EZ10 autonomous shuttles to determine the potential of autonomous shuttles filling in the gaps of traditional public transportation and addressing first and last mile challenges.[23] This partnership with GoMentum Station in Concord, California, marks the first intended deployment of driverless shuttles in the United States. In September 2016, Uber launched its first self-driving fleet in Pittsburgh, home of the company's new Advanced Technologies Center.

Shared mobility

Shared modes of transportation encompasses bikes, cars, shuttles, and other vehicles that users do not personally own, but can use to get where they need to go. The Shared Use Mobility Center defines shared mobility as "transportation services that are shared among users, including public transit; taxis and limos; bike sharing; car sharing (round-trip, one-way, and personal vehicle sharing); ride sharing (carpooling, vanpooling); ride sourcing/ride splitting; scooter sharing; shuttle services; neighborhood jitneys; and commercial delivery vehicles providing flexible goods movement." The public sector has historically operated most shared mobility services, including trains, buses, and paratransit vehicles. But, the array of shared mobility options in the Chicago region is expanding to include a number of private sector services, including Uber, Lyft, Zipcar, and many others. **Table 2** below highlights several

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[21] "Autonomous Vehicles: Self-Driving Vehicles Enacted Legislation," National Conference of State Legislatures, last updated September 21, 2017, http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx.

[22] H.B.0791 100th Illinois General Assembly (2017) http://www.ilga.gov/legislation/billstatus.asp?DocNum=791&GAID=14&GA=100&DocTypeID=HB&LegID=101170&SessionID=91.

[23] Forrest, Conner, "Could the autonomous Mercedes Future Bus lead to driverless public transportation?" Tech Republic, July 19, 2016, http://www.techrepublic.com/article/could-the-autonomous-mercedes-future-bus-lead-to-driverless-public-transportation/.

categories of mobility services and the technologies that have transformed the transportation landscape.

Table 2. Selected taxonomy of technology applications in shared use mobility services.

Service	Role of Technology	Problems Technology May Solve	Factors in Success
Car sharing (examples: Zipcar, car2go)	Reservations and tracking of vehicles; billing	Convenience in making/changing reservations and in locating/dropping off vehicles; national branding encourages use while traveling	Critical mass of users to support availability of vehicles at sufficient array of pickup/drop-off locations
Bike sharing (examples: Citi Bike, Divvy, Capital Bike share)	Reservations and tracking of bikes; billing	Convenience in finding bike share stations and information on bike availability; management of rebalancing	Critical mass of users to support a sufficient array of bike stations; rebalancing of bikes to ensure availability
Transportation network companies (TNCs) -- sequential sharing (examples; Uber, Lyft)	Reservations and tracking of vehicles; billing; quality control via online customer feedback	Convenience of arranging ride just prior to travel; customer tracking of vehicles and wait times reduces uncertainty; national branding encourages use while traveling	Critical mass of users to support widespread vehicle availability; Long-term financial viability of fare structures.
Transportation network companies (TNCs) – concurrent sharing (examples; UberPool, LyftLine, Via)	Reservations and tracking of vehicles; billing; matching of riders for shared rides; quality control via online customer feedback	Convenience of arranging ride just prior to travel; customer tracking of vehicles and wait times reduces uncertainty; national branding encourages use while traveling	Critical mass of users to support widespread vehicle availability; comfort with riding with strangers; critical mass to match riders for shared rides; Long-term financial viability of fare structures.
Microtransit (examples: Chariot, Lyft Shuttle, Bridj)	Reservations and tracking of vehicles; determining routes from public demand; billing	On-board Wi-Fi and efficient routing to match customer demand; customer tracking of vehicles and wait times reduces uncertainty	Critical mass of users to support a variety of routes; comfort with riding with strangers; price points that, while higher than those of standard transit, allow for regular commuting; Long-term financial viability of fare structures
Taxi (or e-hail) (examples: Flywheel, Curb, myTaxi)	Easier reservations, both advance and just prior to travel; billing	Apps may cover multiple taxi companies and estimate wait time, reducing uncertainty; national branding could encourage use while traveling	Critical mass of participating taxi companies; integration with traditional taxi operations; app use by traditional customer base
Transit	Tracking of vehicles; billing; determining routes from public demand	Improve real-time transit info and trip planning, centralize payment and fares across multiple transit systems	App use by traditional customer base; critical mass of users; price points below private modes and sufficiently frequent, fast, and reliable service

Source: Adapted from TRB, Between Public and Private Mobility: Examining the Rise of Technology-Enabled Transportation Services, 2015.

Over the past five years, mobile phones and other technologies have contributed to the increasing visibility and viability of new shared-use modes, particularly Transportation Network Companies (TNCs) like Uber and Lyft. In 2015, half of all American adults were familiar with services like Uber and Lyft, but only 15 percent had ever used them, though that figure is likely higher in major metropolitan areas like Chicago. In the last two years, these services have continued to expand geographically and in numbers of users, with a recent study estimating that 15 percent of all vehicle trips inside San Francisco were Uber and Lyft trips.[24] However, in order for these services to be financially viable in the long term, they will need a critical mass of vehicles in order to provide fast response time, and increase revenue or lower expenses. In 2016, Uber operated at a loss of $2.8 billion.[25] Both Uber and Lyft are heavily investing in autonomous vehicle technology, which would eliminate their need to share revenue with drivers and could increase their profits.

While some shared mobility options directly compete with transit, early evidence shows that some emerging shared mobility options may complement existing transit service, allow more people to forego car ownership or make trips that they would otherwise not have been able to make. A three-year study by scientists at the University of California, Berkeley, found that each Zipcar and car2go car share vehicle removes up to 13 and 11 vehicles respectively from the road.[26] Surveys conducted in 2014 and 2015 by the Shared Use Mobility Center (SUMC) and the American Public Transportation Association (APTA) found that "super sharers" – people who complement public transit with other shared modes (e.g., bike sharing, car sharing, TNCs, etc.) save the most money and own half as many household cars as people who use public transit alone.[27] But, the impact of TNCs and other growing shared mobility services on car sharing is not yet known.

Together, shared mobility services may reshape the land use and transportation infrastructure in our communities. The constant availability of on-demand vehicles and the presence of a robust public transit system could reduce the need for on-street parking and off-street garages. Municipalities may need to reconfigures streets for less parking, but more space for shared mobility users, bikes, and pedestrians. Integrated, multi-modal trip planning apps could facilitate reductions in car ownership and increases in transit ridership. On-demand ride request software also may provide more cost effective and convenient service for people with disabilities, as dial-a-ride and paratransit services represent a resource-intensive and growing

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[24] Rodriguez, Joe Fitzgerald, "Study: Uber, Lyft account for 15 percent of all vehicle trips in SF," San Francisco Examiner, June 13 2017, http://www.sfexaminer.com/study-uber-lyft-account-15-percent-vehicle-trips-sf/.

[25] Lien, Tracey, "Uber doubles revenue but is still bleeding cash, according to a new financial report," Los Angeles Times, April 14, 2017, http://www.latimes.com/business/la-fi-tn-uber-financials-20170414-story.html.

[26] Martin, Elliot, Susan Shaheen, "Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities," Transportation Sustainability Research Center, University of California Berkeley, http://innovativemobility.org/wp-content/uploads/2016/07/Impactsofcar2go_FiveCities_2016.pdf.

[27] "Shared Mobility and the Transformation of Public Transit," Shared Use Mobility Center, March 2016, https://www.apta.com/resources/reportsandpublications/Documents/APTA-Shared-Mobility.pdf.

portion of transit agency budgets. However, people with disabilities, particularly wheelchair users, have faced a lack of accessible vehicles and corresponding longer wait times from private services like Uber and Lyft.

TNCs in particular have unclear impacts on the transportation system. There is some evidence that TNCs may contribute to congestion problems and may compete directly with public transit for riders in more dense urban environments. Studies in Boulder, San Francisco, and New York City found that the extra miles that TNCs generate circling to pick up riders and transporting people who would otherwise have walked, biked, or taken public transit could contribute to increased congestion.[28] [29] These studies also found that TNC usage was concentrated in dense activity centers and during peak weekday travel times. It is difficult to ascertain the impact that TNCs are having on congestion, mobility, and transit ridership because detailed data on their use is not available to public agencies (see next section for more detailed discussion of data).

As with AV technologies, cities and regions are taking a variety of approaches in integrating shared modes into the transportation system. Several cities are piloting partnerships with TNCs in an effort to provide more responsive, cost effective, and higher quality service to people with disabilities and people in less dense areas. One of the most established of these projects is in Pinellas County, Florida, where the Pinellas Suncoast Transit Authority's DirectConnect program subsidizes Uber, Lyft, and taxi rides to designated bus stops from surrounding areas without public transit service.[30] In northeastern Illinois, only one transit agency currently has a relationship with a TNC: Metra selected Uber as its "Official Rideshare Partner" in December 2016 to market last-mile services to customers while also generating non-fare revenue for the agency.[31] The city of Boston is piloting a paratransit partnership that offers subsidized rides in Uber and Lyft vehicles for people who do not need assistance getting into and out of a vehicle. Austin and New York City have imposed regulations on driver screening, data sharing, and surge pricing. The City of Chicago passed an ordinance (effective January 1, 2017) that regulates TNCs by establishing registration procedures for drivers and regulating operation at major destinations like O'Hare International Airport, Midway International Airport, and Navy Pier. Public transit agencies are also developing their own ride sourcing services using similar mobile ride requesting technologies. For example, the Alameda-Contra Costa Transit District is operating Flex, a shuttle service between bus stops within specified service zones that can be booked as little as 30 minutes in advance. Cities across the country are

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[28] Schaller, Bruce, "Unsustainable? The growth of App-Based Ride Services and Traffic, Travel and the Future of New York City," February 27 2017, http://www.schallerconsult.com/rideservices/unsustainable.pdf.

[29] Henao, Alejandro, "Impacts of Ride sourcing -- Lyft and Uber -- on Transportation including VMT, Mode Replacement, Parking, and Travel Behavior," January 19, 2017, https://media.wix.com/ugd/c7a0b1_68028ed55eff47a1bb18d41b5fba5af4.pdf.

[30] "Direct Connect," Pinellas Suncoast Transit Authority, Accessed September 2017, https://www.psta.net/riding-psta/direct-connect/.

[31] Metra, December 14, 2016. Uber names Metra's official rideshare partner, https://metrarail.com/about-metra/newsroom/uber-named-metra%E2%80%99s-official-rideshare-partner.

implementing bike share, and Chicago represents the largest network. The Chicago region's Ventra app is also the first in the nation that allows customers to pay for rides on multiple public transit systems (CTA, Pace and Metra) using the same app. CTA received a FTA Mobility On-Demand grant in 2016 to implement a Ventra-Divvy integration, which will likely be complete in 2018. Private companies are also developing platforms that can allow customers to plan trips across public and private shared use modes.

Transportation data and goods delivery

In the coming decades, the current trend toward larger quantities of data is likely to accelerate, providing new opportunities for rapid, informed decision making in the public and private sectors. The variety and veracity of transportation data will improve, coming from sources such as public agencies, private industry, academia, and civil society. More and more public agencies, including the City of Chicago and the RTA, are leveraging existing administrative datasets for new analysis and developing open data portals to increase the transparency of government data.

Emerging public and private actors are adding to our region's transportation data resources. In 2016, the National Science Foundation awarded the University of Chicago $3 million in Smart Cities-related grants to support the creation of the Array of Things in Chicago, the first such network to serve as an infrastructure for researchers to rapidly deploy sensors, embedded systems, computing, and communications systems at scale in an urban environment. Comprised of 500 nodes deployed throughout the City of Chicago, each with power, Internet, and a base set of sensing and embedded information systems capabilities, the Array of Things will continuously measure the physical environment of urban areas at the city block scale. Several active transportation mobile apps such as Strava, MapMyRide, and Ride with GPS track bicyclist and pedestrian activity, and other companies such as Chicago-based HERE offer data on traffic speeds on roadways. City Digital, a Chicago-based consortium, is planning to launch two pilots that bring together the city, academia and industry to address major urban infrastructure challenges.[32]

Transportation implementers can leverage this wealth of data to unlock promising new research areas, increase prediction accuracy, and support improved decision making. Increased real-time transportation data can provide a deeper understanding of traveler route choices and modal preferences, giving transportation agencies insights on how to respond to the needs of the traveling public and more efficiently use all available capacity across different modes of public transportation infrastructure. The private sector, particularly goods movement companies and TNCs, have already benefited from increased data to improve operations, decrease delivery/travel times, and create new services. The public sector must also identify

[32] "Fact Sheet: Administration Announces New 'Smart cities' Initiative to Help Communities Tackle Local Challenges and Improve City Services" White House Office of the Press Secretary, September 15, 2015, https://obamawhitehouse.archives.gov/the-press-office/2015/09/14/fact-sheet-administration-announces-new-smart-cities-initiative-help.

opportunities to improve public transit, road operations, and growing services like bike share using these datasets.

To fully utilize potential transportation datasets, CMAP and its partners must overcome challenges including data sharing, storage, processing, privacy, and security. Public agencies are generally required to make their data freely accessible, and this data is often an immense source of value to private companies. While many private sector companies have emerged to collect, analyze, and provide insights to public agencies, mobility companies like Uber and Lyft have been resistant to share data with public agencies or participate in open data portals, citing privacy and competitive concerns. Even within the public sector, agencies often face siloed data systems that prevent government from fully harnessing operational data for decision making. The public sector may be less able to collect and manage transportation data as it increases in volume and complexity, and must also navigate competing mandates to provide open access to government data and protect the privacy of residents. Data generated from connected travelers, vehicles and infrastructure may exceed one terabyte of data per Traffic Management Center per day.[33] Private companies are offering an increasing number of services that provide insights and enhanced visualization and tools to people without access to or experience with ArcGIS, machine learning/artificial intelligence, and other data processing platforms. While this reduces the need for public agencies to invest in data storage and processing platforms, this also increases the dependency of public agencies to purchase these tools or services.

A specialized but crucial application of increased transportation data is in the area of goods movement, partly fueled by a shift to online ordering of goods and increasing consumer (both residential and business) expectation of short delivery timelines. Drastic improvements in freight supply chain information across modes and across industries are also expected in the coming decades. Large companies such as FedEx, UPS, and Wal-Mart, have sophisticated software systems that optimize their truck movements, both for long-haul and local trips. Software companies are developing freight movement optimization software which allows for sophisticated optimization of routing and order processing of pickups and deliveries. Optimization areas can include route, forecasted traffic, real-time traffic, incident avoidance, freight/warehouse facility loading dock hours, driver schedule, driver hours of services, and more. The Federal Highway Administration is also developing a freight-centric traveler information system (FRATIS) with the goal of improving intermodal freight operation, reducing freight congestion, and improving air quality near intermodal facilities. In the Chicago region, the Supply Chain Innovation Network is working to encourage off-peak delivery coordination and streamline permitting for oversize and overweight vehicles. Some companies are even investing in R&D on drones that can avoid road network traffic altogether and reduce delivery times to under an hour. The economics of drone delivery are still speculative, and are subject to technological and regulatory hurdles, particularly in dense urban areas with tall buildings and congested airspace. The most likely early market for drone delivery is not for consumer

[33] FHWA, *Integrating Emerging Data Sources into Operational Practice: Opportunities for Integration of Emerging Data for Transportation System Management and Operations*, unpublished.

products, but for small, time sensitive, and valuable cargo, such as medical supplies and samples and urgent documents.[34]

These innovations may have a particularly profound impact on the Chicago region, as a quarter of all freight in the nation either originates, terminates, or passes through metropolitan Chicago. The number of intermodal containers moved through Chicago terminals has risen every year between 2009 and 2015, and volumes of freight movement are anticipated to increase. Changes in freight supply chain management strategies also have significant land use and congestion management implications, as many goods movement companies first invested in large distribution facilities near interstates on the region's periphery, and then began to establish neighborhood distribution centers within urban areas to facilitate more rapid "on demand" delivery.[35] The shift to neighborhood-level distribution networks may accelerate if drone delivery evolves into a major component of the freight system. Shifting freight patterns often leave communities and transportation agencies planning for yesterday's freight system and struggling to anticipate future freight traffic. The shift to on-demand delivery has implications not only for freight and distribution land uses, but for retail land uses as well. Large format retail like shopping malls and big box stores are already in decline, and communities across the region may need to plan for new land uses and revenue sources to replace them. The region will need to develop strategies to track these shifts, plan for major transportation investments, and assist local communities in addressing the challenges these facilities may pose.

Alternative energy and emissions reduction technology

Alternative energy refers to renewable energy sources to be used in place of fossil fuels, which are intended to address concerns such as high carbon dioxide emissions, an important factor in global warming. The highly popular hybrid electric vehicle has led vehicle manufacturers to explore the usage of fully electric, solar-powered, hydrogen fuel cell and other technologies to achieve zero emission vehicles. Innovations in fuel efficiency and alternative fuel technology could develop in parallel with advances in vehicle automation and reduce both air pollution and cost to drivers. Due to increasingly stringent fuel economy standards, vehicles that use conventional gasoline will become more efficient, and more than a quarter of cars and light duty trucks could be powered by electricity and other alternative fuels by 2050.[36] Passenger cars are most likely to be electrified, with a dramatic increase in plug-in and hybrid electric vehicle market share projected by 2050. For heavy duty trucks, the increased aerodynamics associated with platooning could reduce fuel consumption. Modes of human-powered transportation

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[34] Wang, Dan, "The Economics of Drone Delivery," IEEE Spectrum, January 5, 2016, https://spectrum.ieee.org/automaton/robotics/drones/the-economics-of-drone-delivery.

[35] Phillips, Erica, "The New Shopping Hubs for Cities: Warehouse Distribution Centers," Wall Street Journal, April 16, 2017, https://www.wsj.com/articles/the-new-shopping-hubs-for-cities-warehouse-distribution-centers-1492394640.

[36] U.S. Energy Information Administration, Annual Energy Outlook 2017. http://cmap.is/2snwnMk.

such as scooters and bicycles are increasingly employing electric power. Historically, the U.S. electric bike market has been slower to develop compared to countries such as China and Europe. From 2011 to 2012, Americans purchased approximately 100,000 electric bikes, growing to approximately four times that amount in 2014. Experts predict that that the U.S. will become one of the top markets for electric bicycles, selling as many as two million a year within 20 years.[37] Fast-accelerating electric trains have the potential to substantially shorten travel times and improve service for riders by bringing the train up to top speed faster than diesel locomotives.

Solar-powered toll roads and bike sharing stations are other possible solutions that would reduce carbon dioxide emissions and save on energy costs. The E-470 Solar Powered Toll Road in Colorado, which uses solar panels to power road equipment has a projected 20-year energy cost savings of more than $1 million and will be able to save 24,000 tons of carbon dioxide emissions over the same span of time. The energy produced from the 714.9kW photovoltaic system is enough to supply energy for its headquarters building, 18 toll ramps, two toll plazas, one maintenance site, 18 signs, and 15 surveillance cameras.[38]

CDOT is making strides towards replacing on-road fleet vehicles through its Drive Clean Chicago program, which offers point-of-sale discounts for hybrid and electric city vehicles. To date, this program has helped deploy more than 400 cleaner vehicles for Chicago area fleets and over 220 alternative fuel stations, reducing greenhouse gas emissions by 2,850 tons.[39] Pace has recently invested in a fleet of 91 compressed natural gas-powered buses in Arlington Heights, Illinois. Combined annual fuel savings are estimated to be $1 million, compared to using diesel-powered buses.[40] CTA is also continuing to invest in electric buses. CTA and Metra have been working with RTA to assess the feasibility of wayside energy storage systems.[41]

Especially in light of relatively low gasoline prices, battery cost reduction and improved charging infrastructure is needed in order to increase adoption rates of EVs. Economies of scale will not be reached until EV production reaches 50-80 million worldwide. A tightly knit network of home, public, and workplace fast charging stations is critical to increase adoption rates. Incentivizing the installation of fast chargers into multi-unit housing developments and

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[37]Berg, Nate, "If an electric bike is ever going to hit it big in the U.S., it's this one," City Lab, July 29,2014, http://www.citylab.com/commute/2014/07/if-an-electric-bike-is-ever-going-to-hit-it-big-in-the-us-its-this-one/375167/.

[38] IBTTA, "SmartMove: Success Stories from the Tolling Industry: The Solar-Powered Toll Road," October 2014, https://ibtta.org/sites/default/files/documents/MAF/SmartMove_E-470_Solar.pdf.

[39]Drive Clean Chicago, Updated July 2017, http://www.drivecleanchicago.com/.

[40] Pace becomes first transit agency in Chicagoland, third in Illinois to operate CNG buses Pace Media Relations Office, March 29, 2016, http://pacebus.com/sub/news_events/press_release_detail.asp?ReleaseID=658.

[41]CTA, "RFI for a Wayside Energy Storage System 'WESS' in the CTA's Rapid Transit System (Revised)," Issued August 28, 2015, http://www.transitchicago.com/solicitation/detail.aspx?Sid=b7oWoG/RHlV1vneZ4UVJLqg73hfoDoSQxmlz%2B9DYHbQ%3D.

near-term investments in publically available wireless charging stations or electrified roadways can help extend operable ranges of EVs which will make them more appealing for the public to adopt.

Chicago's 100-year old electricity grid network relies mainly on the nuclear, coal-fired, and natural gas-fired energy sources available in northern Illinois. In order for electric fleets to become truly sustainable, the Chicago region would need to make strides towards increasing its percentage of renewable energy generation. In 2014, Illinois was the country's fifth largest producer of wind power with 9.6 million megawatt hours (MWh) of electricity. This accounts for 5.7 percent of the U.S. net electricity generation from wind.[42] High local fuel prices may provide an incentive to explore R&D opportunities in other renewable energy sources, such as advanced liquid biofuels. There is also a need to modernize the energy grid to accommodate increasing electricity demands from private vehicles, public transport, long-distance trains, and bicycles.

[42] Energy Information Agency, "Illinois 2014 EIA Reports and Publications," December 18, 2014, https://www.eia.gov/state/state_one_pager/Illinois.pdf.

ON TO 2050 framework and strategies

CMAP has a significant role in helping the region prepare for and benefit from transformative transportation technologies. Similarly, many of CMAP's partners will be the main implementers, decision-makers, or facilitators of these changes in the region. While we cannot predict the exact technologies of the future, we can understand the potential impacts of today's emerging technology. Actions taken today can guide technology's impact on our built environment, residents, and economy. The following outlines a framework for addressing the uncertainties inherent in emerging technologies, as well as policies and strategies for CMAP and its partners to steer emerging technologies in ways that can benefit the region and meet ON TO 2050 goals.

Regional action in the face of uncertainty

Robust Decision Making (RDM) RDM is an analytical process for examining many plausible futures and systematically testing the impact of alternative policies or actions within each of them. The core principle of RDM is the development of plans that will perform as well as possible, regardless of how the future unfolds. RDM has proven valuable in facing challenges including long-term planning for water resource agencies, coastal restoration in the context of uncertain sea level rise, and military acquisitions to address unknown future threats. This strategy paper uses a simplified, qualitative RDM framework to identify recommendations for taking advantage of, utilizing, and/or preparing for emerging transportation technologies into four different categories. Each of the recommendations is identified as: near-term, shaping, hedging, or deferred adaptive.

Near-term NT

Near-term strategies are anticipated to be effective at achieving objectives in all futures, regardless of risk. These are the most robust actions -- the *no-brainers*. For example, taking advantage of existing transit technologies, and modernizing the public transit and traffic signal systems fit in this category.

Shaping S

Shaping strategies do not necessarily perform well in all plausible futures. Thus there is some risk in undertaking them. Shaping strategies have the potential, however, to promote a desirable future. For example, pilot applications which advance certain transportation technologies may be risky as competing technologies may arise and displace one's efforts, but there is a potential for a preferred technology to gain a foothold in the market through thoughtful pilot development.

Hedging H

Hedging strategies also do not necessarily perform well in all plausible futures. However, they are intended to hedge against a high-risk future that you absolutely seek to avoid. For example, maintaining and defending the right of way (ROW) of public transit services may hedge against a potential future where AVs have led to significant increases in vehicle miles traveled (VMT) and resulting roadway congestion.

Deferred adaptive DA

In some cases immediate action is not needed. If there are potential future signposts or indicators of when action may be needed, some actions can be safely deferred. For example, investment in a public transit fleet of driverless shuttles would be premature, but if and when the technology has proven itself reliable and cost-competitive, the region's public transit agencies could consider that option.

Key strategies

Set the stage for future innovation by identifying and supporting strategic public investments in emerging technology

Continue analysis of impacts and opportunities for emerging technologies in the region NT

To understand the transportation and land use impacts, benefits, and costs of emerging technologies, CMAP should continue to develop information for stakeholders on the near and long- term impacts of new technology. This will require new tools and analytical techniques as well as effort from both the public and commercial sectors to collaborate and provide data and information in a transparent manner. Several topics are already ripe for additional, standalone assessment, including autonomous vehicles, connected vehicles, emerging freight technology and logistics, and TNCs.

CMAP could also play a key role, in coordination with partners in academia and public agencies, in developing analytical tools, and tracking the impact of emerging technologies. CMAP should also conduct an analysis of places where deployment of technologies could provide the greatest benefit to the region, such as where it would be most beneficial to broadcast intersection signal phase and timing or where early adoption of AVs is most likely. Implementers will also need to better understand the long-term financial implications of technology investments. For example, the many transportation agencies in the region who implement and maintain ITS equipment could benefit from a shared understanding and vision for the transition to CVs. CMAP's current role in convening the Advanced Technology Task Force could position the agency to play a role in advancing analysis of connected vehicle opportunities in the Chicago region. CMAP can also closely track and report back on other pilots, including successes, failures, lessons learned, and evaluation of results against our regional goals.

Effectively electrifying vehicles and other public transit assets, including rail, will depend both on adoption of requisite technologies and addressing any related challenges. Any plan for deployment of charging systems or electric locomotives, for example, should consider their impact on land use and the reliability of the distribution grid. Given its role in the regional transportation system, CMAP could help municipalities plan for permitting EV infrastructure and work with RTA to facilitate expanded Metra electrification.

Support innovative and pilot applications of technologies through funding programs S

CMAP has a major role in project prioritization and selection. Regional resources are scarce and there are many needs, but there is an opportunity to prioritize those technology projects with potentially far-reaching impacts in the region, or that can provide immediate benefits that spur future innovation. CMAP and partners with control of transportation funding can enable pilot applications of relatively unproven technology with some risk, ultimately helping the region gain its footing on evolving technologies. For example, CMAP has a track record of using Congestion Mitigation and Air Quality funds to support innovative projects, such as supporting vehicle electrification projects, traditional carpooling incentive programs, and various ITS projects. The Transportation Alternatives Program could also potentially fund investments in technologies that support multimodal transportation options.

One way to facilitate beneficial AV technology advancement and adoption in the region is through pilot testing of AV operations in controlled environments. AV technology is already in operation at O'Hare International Airport with the fully automated Airport Transit System. As public transit agencies look to diversify their service offerings and integrate new technologies, environments such as campuses and office parks may be good testing grounds for pilot transit AV applications. Private AVs could operate in restricted testing areas, which will reduce interactions with non-AVs and ensure pedestrian safety. The RTA's Innovation, Coordination, and Enhancement grant program, currently only available to the transit service boards, could support these types of pilots, in partnership with communities, private sector partners, CMAP, IDOT, and other transportation stakeholders. These pilots could also provide opportunities to identify ways to streamline project delivery and encourage creative contracting mechanisms.

While it is difficult, if not impossible, to predict the exact technologies that will be in use in 2050, it is important to identify the core supporting investments that can enable a wide range of technologies. For example, most innovative transportation technologies, from real-time traffic information to automated vehicles, will rely on a robust communications network. Over the medium term, the region strongly needs to consider improving the fiber optic communications backbone to allow the region to take advantage of improved technology throughout the life of a project.

Establish a regulatory environment that facilitates innovation and supports regional priorities S

In addition to financial and analytical support, CMAP and partners can influence the development of emerging technologies through strategic and coordinated policies. The region should avoid prohibiting or mandating specific technologies and focus on integrating new technologies into existing transportation systems and services in ways that leverage the new services' strengths and help achieve regional objectives around congestion management, emissions reductions, and promoting inclusive economic growth. An example could include identifying and requiring information needed to understand and set policies on private mobility services, such as TNCs. Adoption and promotion of industry standards for communication and technology increases the likelihood that innovation is translatable to and across the region's transportation agencies and municipalities. CMAP and partners should encourage the development of such standards. CMAP and the RTA could play an important role in developing model policies and coordinating throughout the region to avoid a patchwork of inconsistent regulations.

As AV technology matures, carefully consider implications of dedicated roadway allocation for automated and connected vehicles DA

AV and CV technology is likely still decades away from mass adoption, and it is too early to develop concrete plans for dedicating roadway capacity for automated operation. As technology evolves, this issue may become an increasing area of focus, since the greatest benefits of automated and connected technologies accrue when they are not mixed with human-operated vehicles. However, there are many factors to balance when considering dedicated right of way, especially for passenger vehicles. Equity is a particular concern, as these technologies are likely to come with a price premium. CMAP and transportation agencies in the region should carefully monitor the development of AV and CV technologies, but wait to develop any plans for expanded or dedicated roadway capacity until more is known about technology applications. As the region moves forward, implementers should also focus on using existing roadway space to its fullest capacity to accommodate AVs, public transit, and other vehicles, before pursuing expansion options.

Continue to invest in fast, reliable, and modern public transit

Build on traditional public transit strengths S

Public transit is the most fundamental shared mobility, and traditional public transit forms like rail and bus service provide the most cost effective and efficient service in dense population and job centers. Over a century of public investment in the region's rail and bus network should be leveraged to maximize its utility for the future. The region should continue to invest in these services, as they can move many times more people than any other form of transportation, shared or personal, and because they contribute to achieving regional equity goals by providing relatively affordable options throughout the region. The region should identify new dedicated right of way for bus and rail corridors to increase the competitive appeal of public transit as the mode that avoids traffic and provides consistently fast trips, particularly those with high ridership and ridership potential. Public transit agencies and partners should identify places where more dedicated right of way, transit signal priority, and supportive land use policies could make existing service more effective or enable increased frequency or extended hours of service. This recommendation is a major focus of the Transit Modernization strategy paper.

Learn from and integrate private sector trip aggregation techniques to support more nimble public transit services DA

Private sector companies like Via and Uber are getting involved in trip aggregation as part of their services. To make these services as profitable as possible, they are building sophisticated platforms and capabilities to get efficiency out of their services while meeting a complex and dynamic customer demand. There is an opportunity to learn from and adapt these capabilities to more nimble public transit services and develop them as system feeders and first mile/last mile solutions. Some agencies are looking to partner with TNCs and have them provide the services, but there is an opportunity for agencies to institutionalize the technologies and capabilities, not just outsource them.

Explore partnerships with mobility service companies to improve options for difficult to serve markets S

High frequency, high capacity public transit cannot provide universal coverage of the Chicago region. This problem is often driven by low density land uses could transform over time to support higher capacity transit, there is potential to use emerging technologies to better serve low density areas and populations with special needs. Some agencies in other parts of the country have begun addressing first mile/last mile issues through partnerships and subsidies with TNCs. Each of the region's public transit agencies operate in different environments and will have different relationships with TNCs, but RTA and CMAP should develop region wide TNC guidance to assist the agencies in establishing partnerships, ensuring that partnerships are aligned with regional goals including those for land use and equity, provide clear economic benefits to the public transit agencies, and include protections against sudden changes in the private market. Some issues this guidance could address include model data sharing requirements, public safety requirements covering drivers and vehicles, accessibility for people with disabilities, geographic coverage, trip cost, and span of service. Transit agencies will need to maintain their competitive advantage in providing longer trips with greater reliability and less congestion, which will require increased investment in public transit.

Continue to provide and archive real-time public transit data for use in third party applications and evaluation of system performance NT

Seamless trip planning should be an ongoing goal of transportation agencies within the region, especially public transit providers. Many of the innovations and platforms for multimodal trip planning have come from the private sector, and transit agencies can continue to facilitate these services by maintaining high quality data that can be used by third party platforms and applications. CMAP and RTA should consider creating an archive of real-time transit data similar to the data archive CMAP has of expressway system data. This could be an invaluable resource for future research efforts to better understand the transit system operating characteristics and performance trends over time.

Continue development of a universal and seamless payment platform S

A universal and seamless payment platform for transportation costs will improve the competitiveness of public transit and facilitate multimodalism. Ventra is an important step toward an integrated and seamless fare system, and future efforts should explore the potential to integrate emerging private sector shared modes.

Consider integrating automated vehicles into the suite of public transit options as they become available and cost competitive DA

Automated technologies may enable public transit agencies to increase frequency during off-peak times and provide better service to populations and markets that are not as effectively served by traditional forms of transit. As with nearer-term applications of shared modes, once AV-based transit services become cost competitive and available, they may benefit customers who have limited mobility, require paratransit services, or live in low-demand areas. Mid-sized vehicles could serve the role of jitneys, collecting passengers for short trips, connecting them to services such as Metra stations or express bus routes with greater reliability and speed.

Automated buses and trains may also enable cost effective ways to increase frequency of service during late night, weekends, or special events. CMAP, RTA, and transit agencies do not need to take immediate action on this recommendation, but should follow developments in automated shuttle technologies.

Implement policies that discourage low- and zero-occupancy vehicle travel

Identify and employ pricing strategies to manage demand and incentivize higher (2 or more) vehicle occupancy NT

AVs have the potential to revolutionize the demand for mobility, roadway space, and parking space. One of the greatest risks presented by emerging technology is the potential effect of low or zero-occupancy vehicles on congestion and development patterns. CMAP and partners should take steps to identify and analyze roadway and parking pricing policies related to automated vehicles, shared mode, and vehicle occupancy. The region should develop and consider options for pricing roadway use and parking. New pricing strategies can support the competitiveness of high capacity public transit, ensure funding is available for infrastructure and operational maintenance and modernization, and temper the demand for low occupancy vehicle use. When more sophisticated payment collection options are available, dynamic pricing may become a more widely utilized and valuable tool within the region. Congestion pricing via the application of variable toll rates along major expressways would allow prices to rise during the morning and evening peak periods and encourage drivers during peak periods to switch to higher occupancy modes, routes, or times of day. If automated vehicles become prominent, tolls for zero occupancy vehicles should be higher than for occupied vehicles, particularly during peak periods and on congested routes.

Preserve and expand right of way for higher occupancy vehicles and active transportation H

Preserving and expanding right of way, including roadway and curb space for boarding and alighting, for higher occupancy vehicles will be critical to limiting low occupancy vehicle travel. This will be particularly essential in the Central Business District and other capacity-constrained, high-demand parts of the region, but communities throughout the region should preserve space on roads for public transit and use technologies like transit signal priority to ensure that the region's infrastructure can be used to move large numbers of people efficiently. Infrastructure changes can be made to accommodate the evolving shared mobility environment, including investments in traveler information, bicycle and pedestrian improvements, and mandated spaces for car sharing, bike sharing, and carpooling as well as more basic infrastructure such as sidewalks, trails, streetscapes, and signage. CMAP's Local Technical Assistance program can help communities plan for shared mobility infrastructure in ways that prioritize regional goals.

Support walkable, mixed use communities

Continue to prioritize growth and investment in existing communities (S)

A 2017 report from UC Davis points out that many of the best tools for avoiding potential additional auto-oriented development patterns caused by automated vehicles are the same tools planners currently use to encourage infill development.[43] If AVs and other emerging technologies facilitate rapid long-distance commuting, residents will increasingly make decisions on where to live based on other factors, including a community's quality of life. Investing in existing communities can increase their attractiveness to potential residents and prevent the need for costly utility expansions to currently undeveloped areas. CMAP and other stakeholders also have a crucial role to play in educating communities about the benefits of infill development.

As part of the ON TO 2050 development process, CMAP staff have written a Reinvestment and Infill strategy paper that expands on GO TO 2040's broad recommendations to direct growth and investment to existing communities, particularly transit station areas. In particular, promoting non-residential development in infill areas has emerged as an area of strategic emphasis. The report also highlights the need to focus infrastructure, assistance, and other efforts in employment centers, transit-rich or transit potential areas, and disinvested areas that have underutilized infrastructure, prioritizing limited resources to create the strongest impacts. The continuing evolution of mobility services that reduce the need for car ownership have the potential to overcome some barriers to infill development, for example, by making it easier for communities to plan for parking and land use patterns across several adjacent Metra stations and allow more employment and residential development near transit stations. CMAP can help develop best practices for engaging residents and businesses about their concerns over changes in land use, density, and parking availability.

Identify opportunities for flexible design and adaptive reuse as part of local planning (S)

Given the potential for AVs and shared mobility to substantially alter demand for retail and parking spaces, municipalities should encourage new development that can be used for multiple purposes or repurposed as space needs change. For example, the city of Denver requires the ground floor of stand-alone parking garages to be suitable for conversion to active non-parking use.[44] Local plans should identify opportunities to meet both shorter term needs as well as longer term shifts and goals. The Route 59 Metra Station in Naperville offers one example of this, where parking lots were designed to facilitate phased-in, denser development over the long term. CMAP, RTA, and other partners should help identify best practices and provide technical assistance to communities seeking to plan for future flexibility.

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[43] Anderson, Marco and Nico Larco, "Policy Brief: Land Use and Transportation Policies" 3 Revolutions Policy Initiative, University of California Davis Institute of Transportation Studies, April 2017, https://3rev.ucdavis.edu/wp-content/uploads/2017/04/3R.LandUse.Final_.pdf.

[44] Rusch, Emilie, "Denver developers have seen the future of parking and it is no parking at all" Denver Post, October 15, 2016, http://www.denverpost.com/2016/10/15/denver-developers-future-parking-self-driving-cars/.

Another application of flexible design and adaptive reuse is in the repurposing and reallocation of high-demand curb space to accommodate public transit, freight, shared modes, parking, active transportation, and other uses. Communities will need to analyze existing conditions, identify conflicts, prioritize uses that support local conditions, and identify enforcement mechanisms. CMAP can assist communities in these efforts.

Monitor changes in goods movement and better understand land use implications NT

CMAP and partners should increase efforts to track changes in supply chain technologies and practices to support freight's crucial role in the Chicago economy, enhance day-to-day delivery of goods throughout the region, and improve quality of life for residents near freight facilities. In particular, CMAP should work to understand the local impacts of emerging small distribution facilities on traffic, air quality, bike and pedestrian safety, and noise, as well as on the efficiency of goods movement within and through the Chicago region. As automated vehicle technology matures and freight applications become more common, CMAP and partners will need to keep abreast of their effect on local communities as well as on regional freight movement through the expressway system. These changing shopping and supply patterns may also add trucks to local roads. CMAP and communities should encourage continued innovations in safer and cleaner neighborhood-scale delivery vehicles.

Help communities plan for desired freight uses S

Local jurisdictions in northeastern Illinois -- including counties, municipalities, and townships -- regulate land use and development to protect the public health, safety, and welfare. Freight-related land uses can create challenges at both the local and regional scales. Preserving areas dedicated to freight-supportive activity ensures efficient movement of freight, promotes reinvestment in areas with existing freight infrastructure, supports environmental and land conservation goals, and supports the economic base for the region. However, local jurisdictions may have little incentive to modify regulations to facilitate freight-supportive land uses until conflicts arise. At the same time, permissive zoning categories may not align with community plans, leading to new local distribution facilities within transit station areas or areas designated for mixed-use development. CMAP and partners should help municipalities use the land use planning tools at their disposal to integrate industrial and freight development into communities, integrate market feasibility into plans to better match goals with market potential, and align zoning and other regulations with community plans to ensure that development meets feasible community goals.

Emphasize data collection and sharing as a regional priority

Continue to encourage the public sector to collect and share data NT

CMAP, RTA, and other transportation agencies provide and process significant data for the region. As data continue to grow in value and availability, this role will only grow more important. CMAP will continue to have a major role as a regional data aggregator and can continue to address data gaps and promote data consistency and availability throughout the region. CMAP can promote responsible data stewardship among partner agencies such as the City of Chicago, RTA, transit providers, counties, and communities, and may be able to play a role in helping cost-effectively collect, process and store transportation data. Given the increasing value of accurate, comprehensive, and timely roadway data to AV manufacturers and mobility companies, the public sector should identify ways to leverage provision of more detailed data and analysis to private companies while still protecting riders' privacy.

Work with partners to increase data sharing between public and private sector S

The next decades will involve a substantial amount of work determining what data is useful and what data is still needed. Much more research is needed in order to determine how well new mobility management strategies (e.g., one-way trips, peer-to-peer car sharing, shared-used modes, trip planning apps) are working and whether they are supporting regional performance goals. While regional data-sharing, especially between public and private sector entities, is always a challenge, the region should continue to emphasize open data sources and standards for privacy protection. CMAP can encourage private sector partners to share data and, where possible, require it contractually as a condition for access to public infrastructure or subsidies. Implementation of this recommendation will need to be led by a variety of stakeholders, most notably the major data asset holders, including transit and transportation agencies, other government agencies with transportation data, and potential private sector partners. There are opportunities to engage in more partnerships among research universities in the Chicago region (i.e., University of Illinois at Chicago, Northwestern University, University of Chicago, Loyola University, DePaul University, etc.), which have experience protecting personally identifiable information in large-scale analyses.

Ensure emerging technologies support inclusive economic growth

Pursue innovative, affordable mobility solutions for low income residents S

If new premium mobility options cause declining transit ridership, public transit agencies may struggle to provide services that provide crucial access to jobs and other destinations for those who cannot afford car ownership. While investing in frequent service on high ridership corridors, transit agencies must also find ways to improve mobility for low income residents and communities in areas with limited public transit service, or travel needs that are not well served by traditional transit options. Shared mobility and automated vehicle technologies have the potential to provide more frequent and direct service in low income neighborhoods, and improve connections to jobs that may currently require long transit trips or connecting multiple modes. CMAP can play a role in identifying gaps in the transportation ecosystem for economically disconnected communities, and work with public transit agency and private sector partners to identify solutions.

Support land use planning and transportation investments in lower capacity or lower income communities S

Communities with limited resources will be less able to anticipate and respond to changing land use and traffic patterns caused by evolving transportation technologies. They may also be less able to purchase sensor, communication, and data processing equipment that could allow them to reap the benefits of new technology. For example, AVs could continue and accelerate an existing trend in disinvested communities of increased vehicle speed on roads designed to accommodate higher volumes of human-operated vehicles. Without thoughtful planning, biking and walking in these communities may become increasingly difficult and dangerous. At the same time, innovate technologies could reduce the need for car ownership and lower overall transportation expenses, attract new investment, and better serve residents of economically disconnected communities. CMAP should devote local planning resources to helping communities identify the potential benefits and pitfalls of new technologies with regard to economic success and quality of life. IDOT, counties, and other transportation providers should ensure that disinvested communities are not adversely impacted by or excluded from improvements intended to facilitate new vehicle types and technologies.

Analyze opportunities and needs for new skills and jobs due to technological changes in transportation and the freight cluster NT

Transportation technologies, including advances in freight and logistics technology and automated vehicles, may affect the numbers and types of jobs available in the Chicago region in the future constraining job growth in some areas and creating new, unforeseen opportunities. CMAP's past regional economy work already analyzes trends in the region's traded clusters and the impact on employment in the region. CMAP and other stakeholders should continue this analysis, and include discussion of changing freight industries on employment, training, and job accessibility, particularly in economically disconnected communities.

Appendix: Interviews

For this project, researchers at Cambridge Systematics interviewed the following group of transportation technology leaders and visionaries to gain their insights on emerging technology trends and issues. Among them were public and private sector technology developers, analysts, and users with an expertise in wide-ranging domains.

- **John Corbin**, Transportation Specialist at the Federal Highway Administration Resource Center, *ITS technologies.*
- **Scott McCormick**, President of Connected Vehicle Trade Association, *connected/autonomous vehicles.*
- **Valerie Shuman**, Principal at Shuman Consulting Group, LLC and Vice President of Connected Vehicle Trade Association, *connected/autonomous vehicles.*
- **Josh Meyer**, Vice President of Strategic Planning – Aftermarket Division at Robert Bosch LLC, *aftermarket devices.*
- **Jonathan Levy**, Open Data Program Manager at Chicago Department of Innovation & Technology, *data.*
- **Monali Shah**, Director of Global Intelligent Transportation Solutions at HERE, *data.*
- **Michael Horvath**, Chairman and President at Strava and **Brian Devaney**, Marketing Lead at Strava, *active transportation data.*
- **Sara Rienhoff**, Platform Principal at Via, *ridesharing.*
- **Sean Wiedel**, Assistant Commissioner at Chicago Department of Transportation and **Samantha Bingham**, Environmental Policy Analyst at Chicago Department of Transportation, *bike sharing.*
- **Joseph Kopser**, President at moovel Group North America, *transit app developer.*
- **Chris Ricciardi**, Chief Product Officer at Logistical Labs, *business logistics.*
- **Steve Viscelli**, Senior Fellow in the Department of Sociology at University of Pennsylvania, *freight.*

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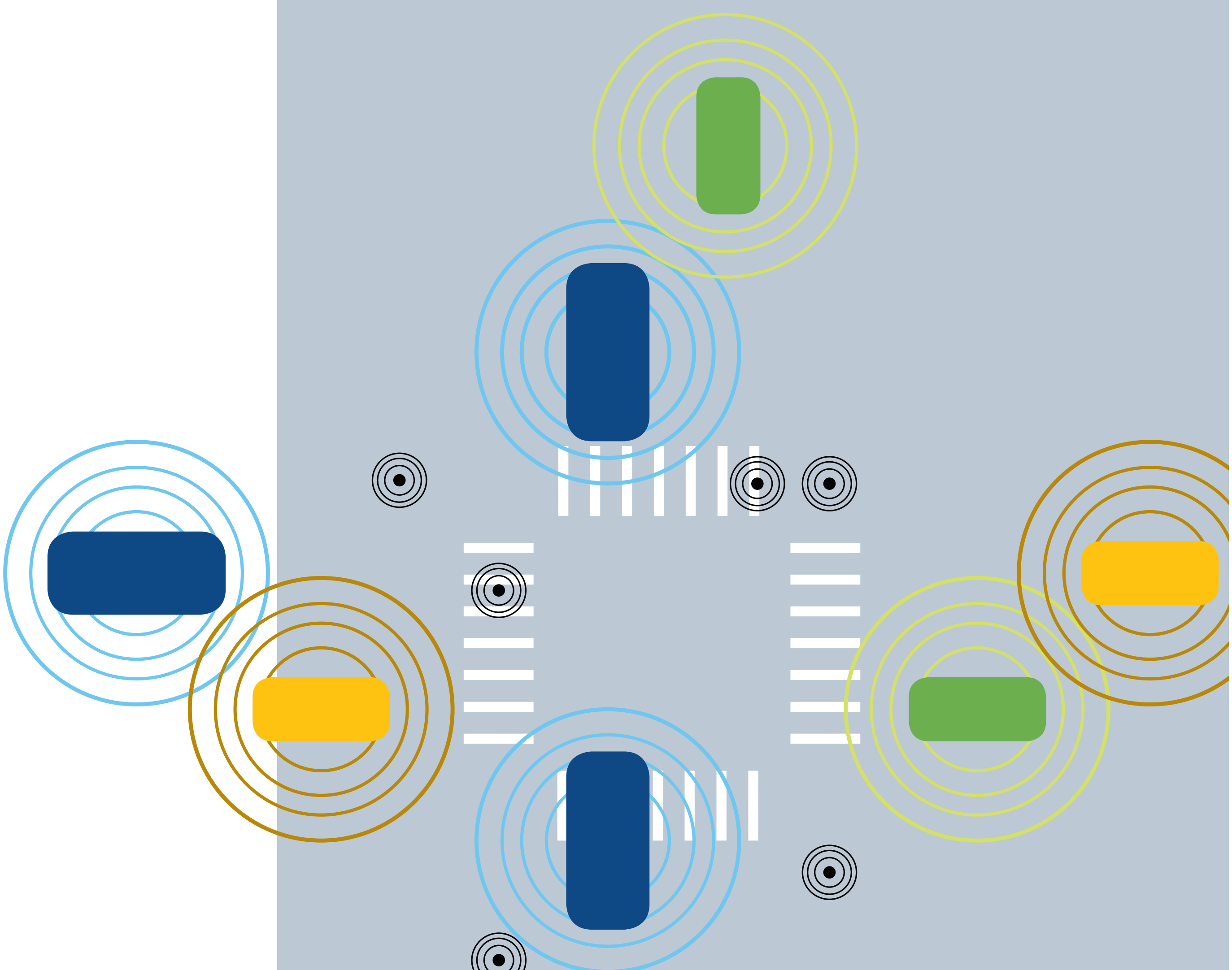
The Chicago Metropolitan Agency for Planning (CMAP) is our region's comprehensive planning organization. The agency and its partners are developing ON TO 2050, a new comprehensive regional plan to help the seven counties and 284 communities of northeastern Illinois implement strategies that address transportation, housing, economic development, open space, the environment, and other quality-of-life issues.
See **www.cmap.illinois.gov** for more information.

ON TO 2050 strategy papers will explore potential new topics or refinements to existing GO TO 2040 recommendations. These documents and data-driven snapshot reports will define further research needs as the plan is being developed prior to adoption in October 2018.



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