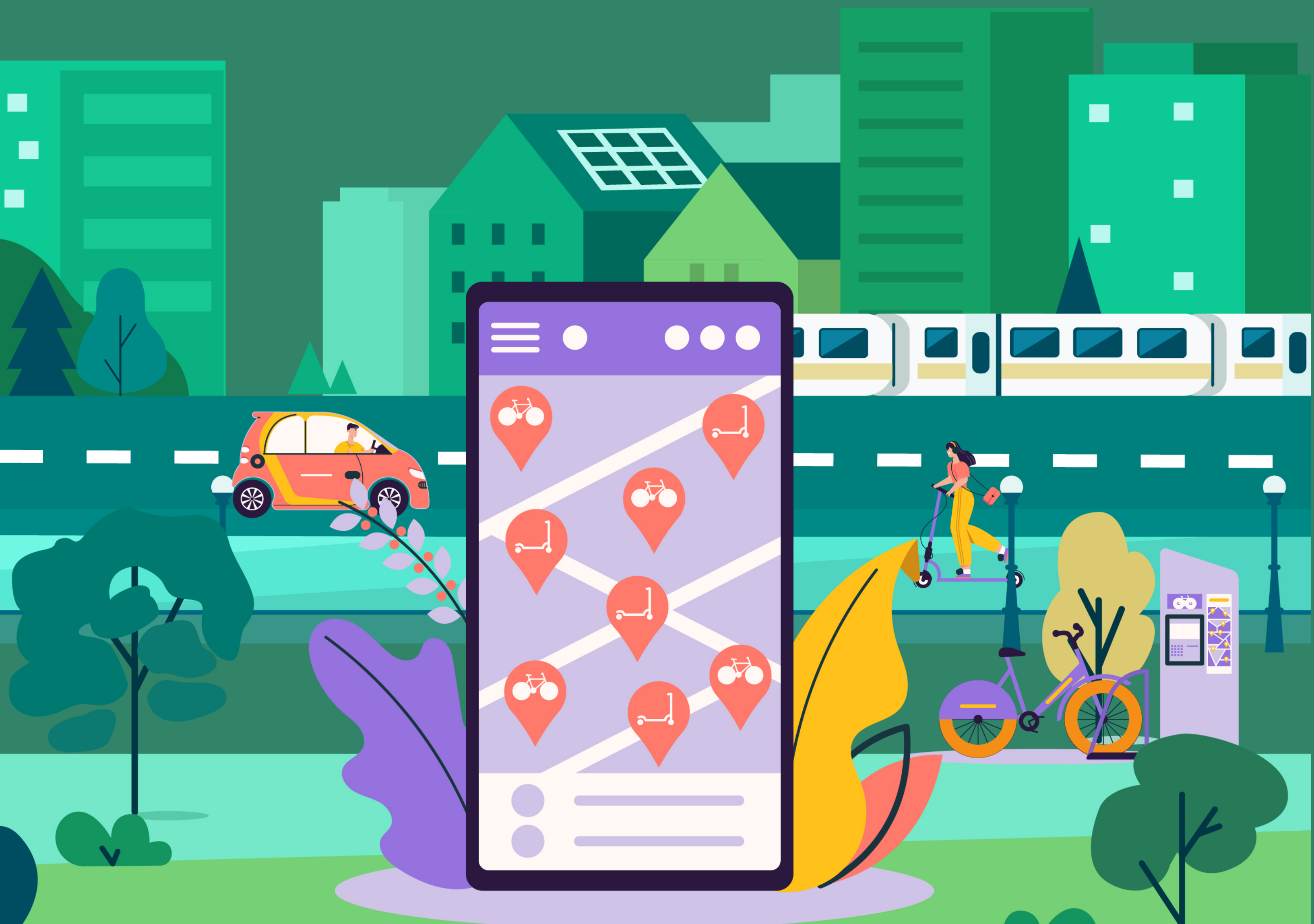
Montgomery Planning

Disruptive and Emerging Technologies White Paper



Disruptive & Innovative Technologies

Mobility as a Service (MaaS)

The transportation industry is at a synergistic crossroads of multiple technological advancements. Innovations in big data, communications, energy production and storage, computer processing, sensor-perception systems, machine learning, and artificial intelligence are revolutionizing the transportation industry. It is estimated that the levels of disruption and innovation in the transportation industry in the next 12 years will exceed those in the previous 50 (McKinsey & Company, 2019). With the ubiquitous adoption of smartphones and seamless sharing information via the "internet of things" (Iot) and the emergence of the "sharing economy," the concept of Mobility as a Service (MaaS) is growing in popularity. MaaS is the idea that one does not need to personally own a vehicle to satisfy their mobility needs. It is a user-centric and technologically driven experience that seeks to integrate "a full range of mobility options in one digital-mobility-platform offering with public transportation as the backbone" (APTA, 2019).

Successful MaaS examples abound in Europe with Helsinki, Finland leading the charge. A key component of a successful MaaS platform is the integration of all mobility options, including payment methods, into a single application. To achieve this, cities such as Helsinki have passed laws that require all providers of transportation services, both private and public, to release open and free application programming interfaces (APIs) for seamless integration into MaaS applications (Bonfils, 2019) (Figure 1).[1] A recent survey of 1,000 adults nationwide suggests that 74 percent of millennials would regularly use a MaaS application (APTA, 2018). RethinkX, "an independent think tank that analyzes and forecasts the speed and scale of technology-driven disruption and its implications across society," forecasts that by 2030, "the average American family will save more than $5,600 per year in transportation costs" by foregoing their private vehicle and relying on MaaS for their mobility needs (Arbib and Tony Seba). This conclusion was based on a very bullish estimation that electric autonomous vehicles will penetrate the ride-hailing market and influence the public's willingness to forego private automobiles. These topics, among other disruptive technologies, are discussed in more detail in the following sections.

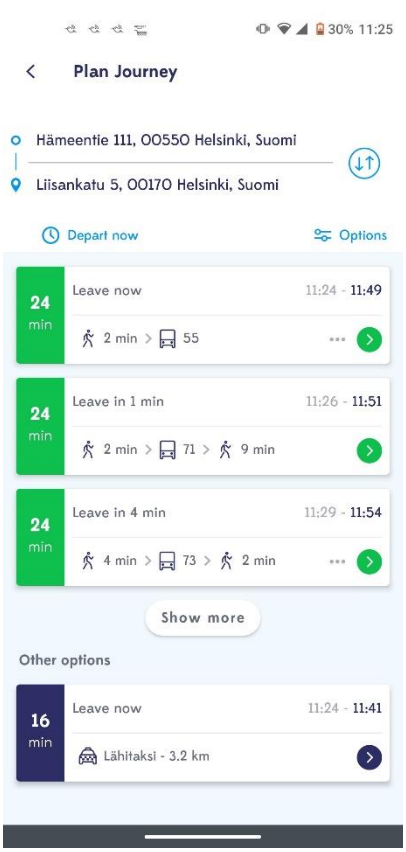


Figure 1: Example of MaaS application Interface

Transportation Network Companies

Often referred colloquially as "ridesharing" (a misnomer) or "ride-hailing," transportation network companies (TNCs) have certainly been a disruptive force in the transportation industry. It is important to note that the related concept of "carsharing" has been around for more than two decades. Early carsharing business models offer a station-based experience where both pick-up and drop-off are

[1] Example of the "Whim" MaaS mobile application that integrates both private (in blue) and public (in green) transportation options.

required to occur at the same location. Later business models introduced greater pick-up and drop-off flexibility, which required agreements with local governments to define appropriate zones and locations for such activity. Following the recent sharing economy trend, a new phenomenon in the carsharing world is peer-to-peer (P2P) car sharing. Like AirBNB, P2P carsharing applications facilitate the ability of car owners to list their vehicles for rent. According to recent estimates, "the number of P2P car-sharing vehicles globally grew from approximately 200,000 in 2015 to more than 440,000 this year, and that figure is expected to more than double by 2025, to approximately 990,000 vehicles" (Schmidt and Deryckere, 2020). Waze, by way of Google, has also recently launched a carsharing app. The company claims it has helped reduce carbon emissions by 20 million pounds in 2018 and expects its platform to facilitate 20 million monthly rides in 2020 (Hawkins, 2019). Prior research indicates that adopters of carsharing services own fewer cars and drive fewer miles than their non-carsharing counterparts, even when controlling for the built environment (Clewlow, 2015).

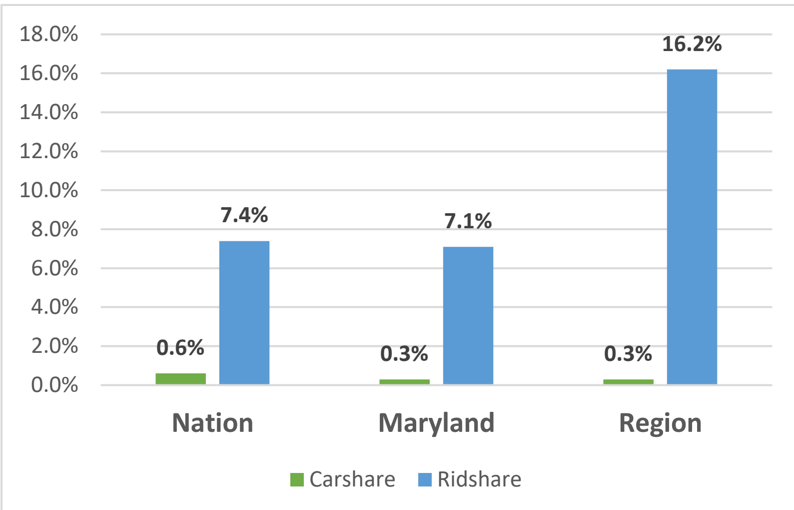


Figure 2: Percentage of Persons Who Reported Utilizing Carsharing or Ride-Hailing Service During the Past 30 Days

Ride-hailing services and options, however, are far more ubiquitous and penetrate a much broader market than the niche clientele of the carsharing industry (Figure 2)[2,3]. These services have provided a flexible mobility option for millions of people, but there have also been unintended consequences that magnify the negative externalities borne by society caused by automobiles (more on this in a subsequent chapter). A major concern of ride-hailing services is that they increase vehicle miles traveled (VMT), and consequently, greenhouse gas (GHG) emissions. For example using a blend of aggregated data from seven major U.S. metropolitan areas and surveys from the State of California, the Union of Concerned Scientists estimated that non-electric and non-pooled ride-hailing trips generate 69 percent more GHG emissions than the trips they displace (Anair, Don, Martin, Pinto de Moura, and Goldman, 2020). This is due to a combination of "deadheading," the time a ride-hailing vehicle spends driving without a passenger, and the lower emission transportation alternatives ride-hailing services are estimated to displace.

For example, TNC trips are typically segmented into three phases. Phase one represents when a driver is logged into the application and is waiting for a service request. Phase two occurs when a driver has been matched with a passenger(s) and is in route to retrieve the rider(s). Finally, phase three initiates when the passenger enters the vehicle and terminates when the passenger fully exits the vehicle (Nevada Division of Insurance, 2020). A recent study using data provided by two major TNC companies estimated that deadheading (phases 1 and 2) accounted for approximately 44.6 percent of the total VMT

[2] Federal Highway Administration. (2017). 2017 National Household Travel Survey, U.S. Department of Transportation, Washington, DC. Available online: https://nhts.ornl.gov.

[3] Region is defined as Montgomery and Prince George's Counties.

generated by ride-hailing trips (Figure 3) and 6.9 percent of the total regional VMT in September 2018 (Fehr and Peers, 2018).

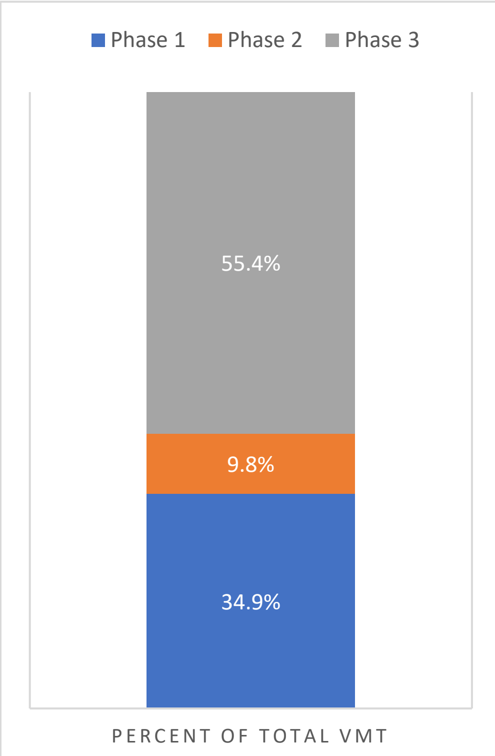


Figure 3: TNC VMT Breakdown By Phase in the Washington DC Region

It should be noted that a complicating factor in analyzing TNC data across multiple providers is the issue of "double-apping." Double-apping occurs when a driver simultaneously "clocks" into two or more ride-hailing apps. A recent survey indicated that approximately 23 percent of ride-hailing drivers equally split time between two leading TNCs. (Campbell, 2020). The breakdown of VMT by trip phase presented here assumes a midpoint between a high and low estimate of the double-apping phenomenon (Fehr and Peers, 2018).

Another impact to the transportation system of TNCs is the shift from more efficient and environmentally friendly modes to the automobile. Research indicates various findings depending on the data sources and methodologies (aggregate data vs convenience surveys vs representative surveys). For example, a survey of 4,500 "shared-use mobility" consumers that was administered by public transit agencies and private shared mobility operators indicated that TNCs played an important role in "supersharers'" ability to drive less than transit-only users. Supersharers are defined as respondents who, in addition to transit, used some combination of non-transit shared modes (bikesharing, carsharing, or ridesourcing). These supersharers are 10 percent less likely to have reported to drive alone and own far fewer cars than "transit only" respondents (0.72 cars vs. 1.5 cars). The report goes on to conclude that "the more people use shared modes, the more likely they are to use public transit, own fewer cars, and spend less on transportation overall" (American Public Transportation Association, 2016).

In May of 2016, the two leading providers of ride-hailing services ceased operations in Austin, Texas due to disagreements with the City over driver vetting procedures. Researchers surveyed 1,840 TNC users to understand how their travel behavior changed after the disruption of TNC services. Researchers found that "45 percent [of survey respondents] switched to the use of personal vehicles after disruption while only three percent shifted to public transit. Individuals who switched to personal vehicles also include 8.9 percent of respondents who reported purchasing a vehicle in response to the service disruption." TNC users, however, residing in Austin's urban core were 20 percent less likely to make the switch to a personal vehicle than suburban TNC users (Hampshire, Simek, Fabusuyi, Di, and Chen, 2017). Other studies that rely on random surveys or longitudinal aggregate data, however, typically find availability and growth of ride-haling services impact transit ridership more significantly.

A targeted and representative survey deployed in seven U.S. cities found that TNCs have a nuanced impact on transit. Evidence from the survey seems to suggest that TNCs detract from non-premium transit such as traditional bus service but may complement more premium transit service such as heavy rail. Researchers estimated that, on average, respondents who reported a change in their mode split reduced their public bus usage by about six percent while increasing their reliance on heavy rail by about three percent. Respondents also reported walking approximately nine percent more after the adoption of ride-hailing services. The extent of their reliance on walking, however, is unclear (majority of the trip vs "last mile connections"). Similar to the aforementioned Union of Concerned Scientists study, researchers concluded that "that 49 percent to 61 percent of ride-hailing trips would have not been made at all, or by walking, biking, or public transit. This 'mode substitution data' suggests that directionally ride-hailing is likely contributing more vehicle miles traveled (VMT) than it reduces in major cities" (Clewlow, Mishra, 2017).

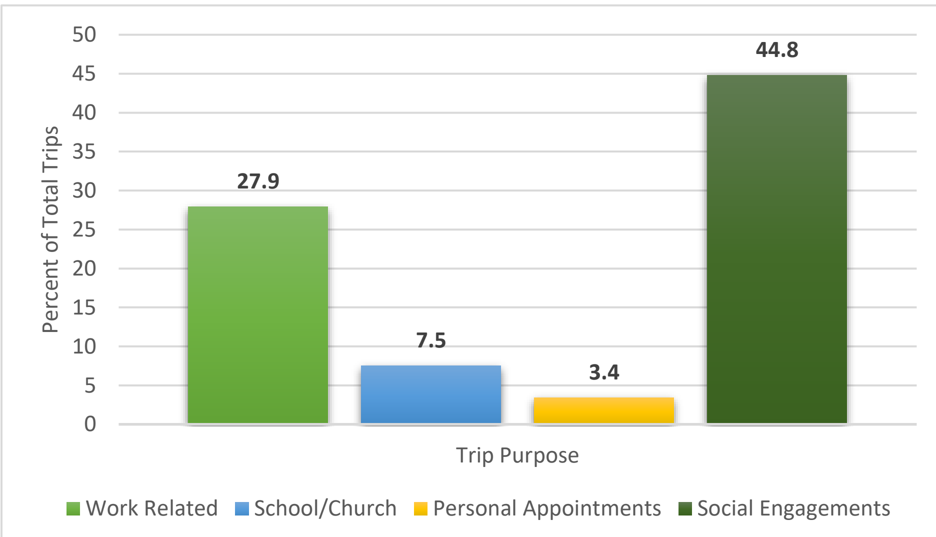


Figure 4: Breakdown of TNC trips by Purpose in Region

The Institute for Transportation and Development Policy (ITDP) acknowledges the benefits and utility that TNCs can provide society, however, notes that a holistic management framework is imperative. One such potential benefit is providing mobility opportunities to the elderly. Currently, there is a significant technological barrier to seniors using TNC services. A recent study, however, demonstrated that once these technological barriers are removed, TNCs can provide elderly citizens with much needed mobility options. Three months of free and unlimited TNC services were offered to 150 elderly residents in the Los Angeles, California region. Ride-hailing application training was provided to all participants prior to the initiation of the study. At the conclusion of three months, 93 percent of the subjects utilized TNC services for an average of 69 rides. Most of the trips were to access medical appointments or social engagements. More than 80 percent of the participants reported that they would continue to use TNC services in the future. Medical researchers concluded:

> "older adults adopt and use networked transportation to access medical care, as well as fitness, social, and leisure activities, thus improving their perceived quality-of-daily-life [and] are motivated to break down the barriers disrupting their own health and are willing and are even enthusiastic about adopting novel technology solutions in order to do so, but education and support remain key elements in rates of success" (Saxon, Ebert, Sobhani, 2019).

Research also indicates that ride-hailing services are most often used for social engagements that typically occur during off-peak transit hours. According to a representative survey, by far the most common purposes of TNC trips were to access bars or attend parties, and the top reason to use ride-hailing services was "to avoid driving when I might use alcohol" (Clewlow, Mishra, 2017). Data from the National Household Transportation Survey for the Washington, DC region indicate similar patterns (Figure 4).[4] In totality, the research seems to indicate that there are likely various typologies of ride-hailing users. For many it serves as one tool in the toolkit to live a car-free life, particularly in urban areas. For others, it simply supplements an auto dependent life. For the transportation system as a whole, however, it certainly has been a disruptive force and added to the woes caused by our overreliance on the automobile. In order to ensure TNCs support a sustainable transportations system, the ITDP conducted four case studies and interviewed several public and private representatives with extensive TNC regulatory experience. ITDP concludes:

> "TNCs will never substitute for a robust transit network or compact, pedestrian-friendly development. However, they can provide safe, reliable, affordable connections to transit, as well as flexibility for more complex trips that require carrying goods, traveling with a companion who has limited mobility, and so on" (ITDP, 2019).

ITDP'S TNC POLICY APPROACH

Step 1: Adopt an iterative decision-making framework that links TNC operations to broader citywide goals.

Step 2: Ensure that TNC regulations address all four of the following critical regulatory elements:

- ✓ Pricing: Incentivize shared, shorter, less frequent trips Metrics: Establish baselines to better understand TNC impacts.
- ✓ Data: Use operator data for policy enforcement and evaluation.
- ✓ Regional coordination: Facilitate connectivity through multijurisdictional regulation.

Step 3: Identify and work to minimize any structural barriers that may prevent or limit the implementation of a comprehensive TNC regulatory strategy.

Shared Micromobility

The International Transport Forum (ITF) defines micromobility as personal transportation via "devices and vehicles weighing up to 350 kg [772 lbs] and whose power supply, if any, is gradually reduced and cut off at a given speed limit which is no higher than 45 km/h [28 mph]." Additional subclassifications (Figure 5) based on top speed and weight are also proposed (ITF, 2020). Since micro-vehicles "are polymorphic," this nuanced but broad classification scheme can serve as a foundation for common understanding and specific application of regulations and infrastructure design.

Shared micromobility "is an innovative transportation strategy that enables users to have short-term access to a mode of transportation on an as-needed basis" (Shaheen, Cohen, 2019). Typical examples of such services include station-based bikesharing, dockless bikesharing, standing electric scooter sharing,

[4] Federal Highway Administration. (2017). 2017 National Household Travel Survey, U.S. Department of Transportation, Washington, DC. Available online: https://nhts.ornl.gov.

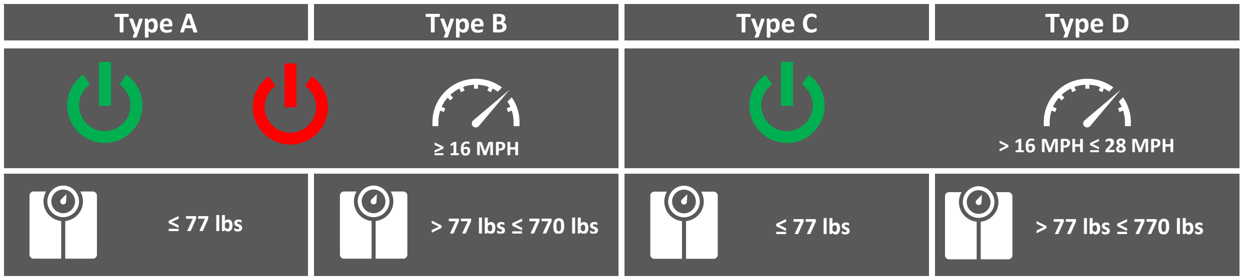


Figure 5: Micromobility Classification Example ([ITF, 2020])

and more recently, moped-style scooter sharing. There has been a rapid growth in shared micromobility services, that more recently, have largely been driven by dockless scooters entering into the market. For example, in 2020 there were almost 24,000 more trips made in Montgomery County on dockless vehicles, with a predominant amount being e-scooters, than via a traditional docked bicycle (Figure 6). On average, in 2020 there were approximately 169 daily docked bikeshare rides and 238 daily dockless rides.

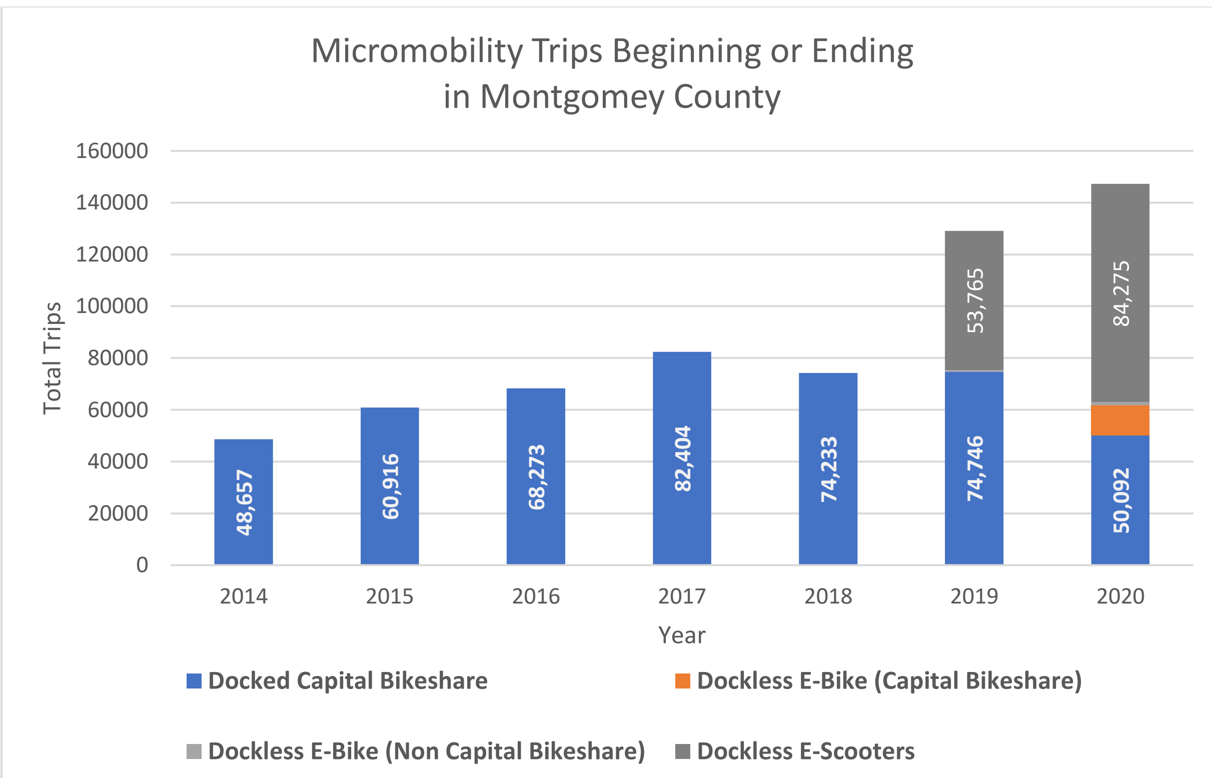


Figure 6: Micromobility Usage in Montgomery County[5]

[5] 2019 Dockless trip data (Dockless E-Bike (Non Capital Bikeshare & E-Scooters) is from June 27th through December 31st. Data feeds were suspended from June 2, 2020 through June 9, 2020. In addition, 53,779 dockless Capital Bikeshare trips occurred in 2020 that could not be located due to a lack of location information. These trips are not reflected in Figure 6.

Shared mobility devices (SMD) diversify local transportation options with both intended and unintended consequences. The impact on travel mode seems to depend on the built environment. Shared mobility systems in dense urban environments appear to shift trips away from public transportation, but shift trips towards public transportation in more suburban environments. For example, after docked bikesharing was introduced in Washington, DC, 47 percent of surveyed users shifted away from rail compared to seven percent who shifted toward it. Similar shifts were found for bus ridership (Shaheen, Cohen, 2019). In Alexandria, Virginia, approximately 70 percent of SMD users indicated "they would have either used a personal vehicle, used a rideshare app, or taken a taxi" if they were not offered an e-scooter (City of Alexandria, 2019). A survey conducted in Arlington, Virginia found that 32 percent of respondents indicated that they forwent a vehicle trip due to the availability of e-scooters.

LEGISLATION WATCH

Electric Bicycle Incentive Kickstart for the Environment (E-BIKE) Act

On February 9th, 2021, US Congressmen Jimmy Panetta (CA) and Earl Blumenauer (OR) introduced the E-BIKE Act. The E-Bike Act creates a consumer tax credit that:

- Covers 30 percent of the cost of the electric bicycle, up to a $1,500 credit
- Applies to new electric bicycles that cost less than $8,000
- Is fully refundable, allowing lower-income workers to claim the credit

The rise in dockless e-scooter and e-bike popularity has raised safety and infrastructure concerns. It is difficult to assess the comparative safety of SMDs with other modes such as traditional bicylcing, walking, and vehicle travel. This is due to the difficulty of quantifying the exposure of pedestrians and cyclists to normalize crash statistics. A study that normalized e-scooter and cyclist crashes with approximate exposure (millions miles traveled) in Washington, DC, estimated that for every one million miles traveled, 20.7 e-scooter riders and 6.1 cyclists sought treatment at an area hospital (Cicchio, Kulie, McCarthy, 2020). Arlington, Virginia found that "qualitatively normalized measures of e-scooter crashes are lower than pedestrian but higher than bike crashes"(DeMeester, Mjahed, Arreza, Covill, 2019). The city of Baltimore, Maryland normalized automobile and e-scooter injuries by the number of users of each mode within the city (licensed drivers and unique scooter users). The city estimated 8.8 vehicle injuries and .66 e-scooter injuries per 1,000 drivers/scooter users.

Curbside management and other infrastructure concerns are often raised with regards to dockless SMDs. Without the presence of a physical docking station or designated parking locations, it is up to the user to park the vehicle in an appropriate location that is safe and unobstructive to all other users of the curbside. Surveys from various pilot surveys from around the region indicate a significant concern with regard to parking. In Arlington, "65 percent of non-SMD riders reported often to always encountering blocked sidewalks due to e-scooters being improperly parked"(DeMeester, Mjahed, Arreza, Covill, 2019). In Alexandria, 75 percent of respondents to a an e-scooter pilot evaluation survey indicated that improper parking was a concern (City of Alexandria, 2019). A community survey conducted in Downtown Silver Spring and Takoma Park, Maryland to evaluate the 2017 dockless e-bike pilot program also indicated that 75 percent of respondents thought parking strategies needed to be improved (MCDOT, 2018).

Field observations, however, may indicate that issues of parking may be anecdotally exaggerated. The same pilot evaluation found that 86 percent of bikes were parked upright and in appropriate locations. A more extensive evaluation of parked scooter locations in San Jose, California found that "that fewer than two percent of scooters blocked access for people with disabilities and 90 percent were parked out of the way of pedestrian traffic" (Shaheen, Cohen, 2019). Just one improperly parked SMD, however, can be a major disruption to the flow of pedestrian traffic and be a major barrier for people with disabilities. The National Association of City Transportation Officials (NACTO) published guidelines for regulating Shared Micromobility and recommends installing clearly marked parking locations in high traffic areas such as street corrals, docking points, and marked locations on sidewalks (NACTO, 2019). Some have also advocated for "adopting policies that encourage or require scooter parking on private property" (Shaheen, Cohen, 2019).

Evolution of the Automotive Industry

Automotive ingenuity has historically been rooted in hardware and mechanical improvements. Current investments, however, indicate that there is a race to transform automobiles into robust software platforms with big data and seamless connectivity as their foundation. Technological giants such as Google and Apple are now players in the automotive industry as we accelerate towards an autonomous, connected, electric, and shared automotive future. A market analysis conducted by McKinsey & Company found that approximately $220 billion have been invested in the automotive industry across 10 technology clusters between 2010 and 2019 (Figure 7). By comparison, it is estimated that $47 billion was invested in 1,200 miles of new and expanded transit lines between 2010 and 2019 (Freemark, 2020).

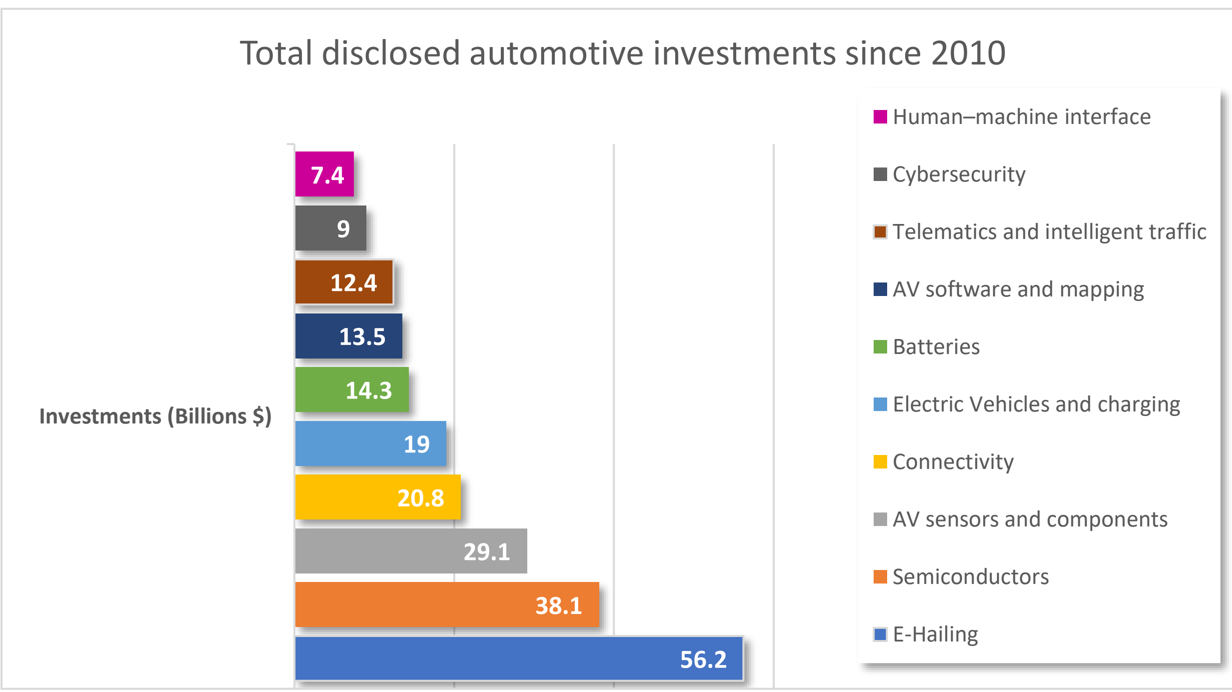


Figure 7: Automotive Investments since 2010 across 10 technology clusters[6]

[6] McKinsey & Company (2019). Start me up: Where mobility investments are going, New York, New York. Available online: https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/Start%20me%20up%20Where%20mobility%20investments%20are%20going/Start-me-up-where-mobility-investments-are-going.ashx

Autonomous Vehicles

With billions of dollars being invested in autonomous and connected vehicle related technologies, it is sometimes difficult to differentiate between hype and reality. There are now many driver-assistance technologies offered by automakers that often have catchy names such as Tesla's "Autopilot," Cadillac's "Super Cruise," and Ford's "Co-pilot 360" that seem to suggest an element of full autonomy. The reality is however, that none of these options offer level 5 autonomy as defined by Society of Automotive Engineers (Figure 8).

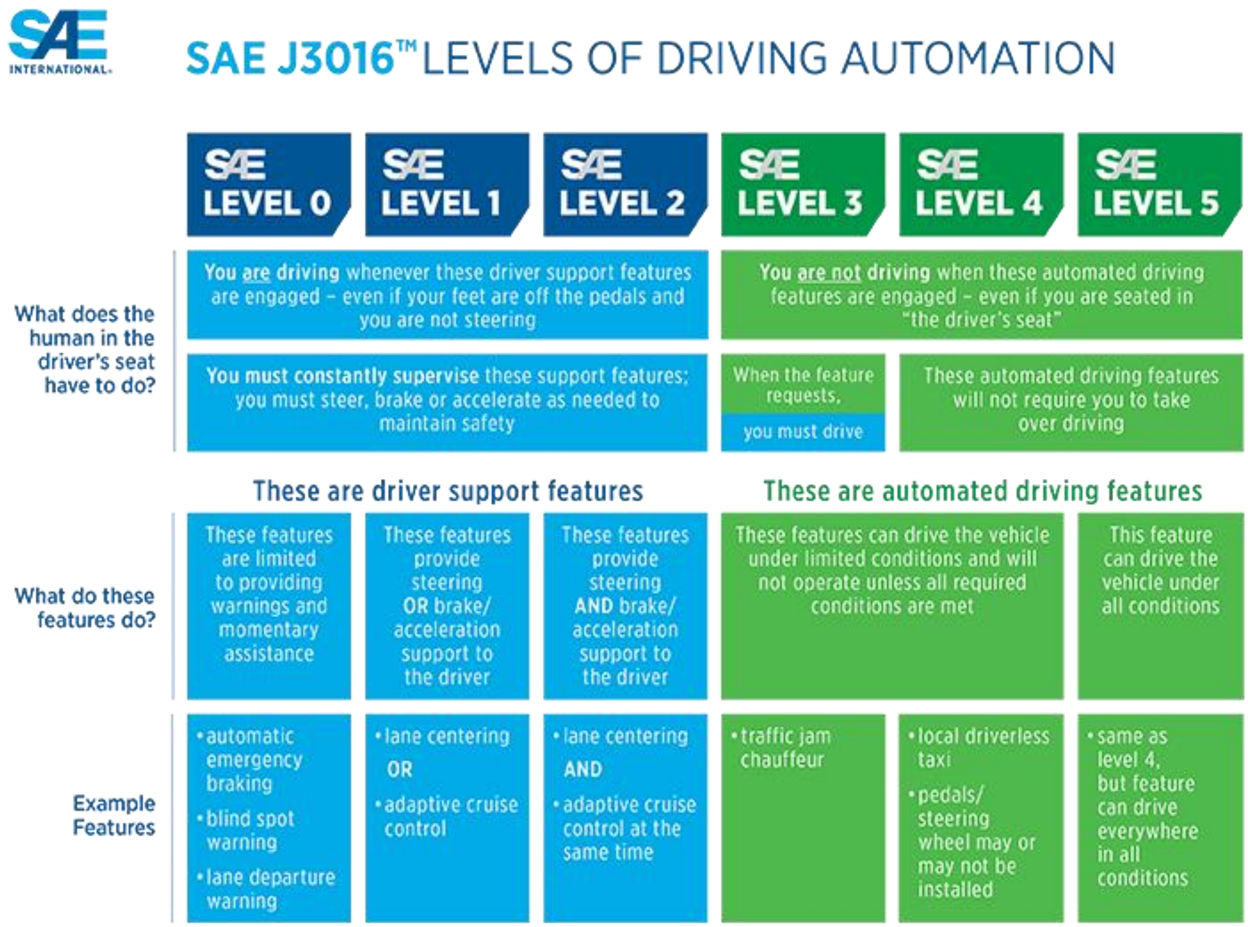


Figure 8: Visual Chart Depicting SAE International's Level of Driving Automation[7]

In recent years, many automakers have had to backtrack on overly optimistic predictions regarding mass availability of level 5 autonomous vehicles. The effort and time to move from automation level 3 to level

[7] Society of Automotive Engineers (2018). SAE International Releases Updated Visual Chart for Its "Levels of Driving Automation" Standard for Self-Driving Vehicles, Warrendale, PA. Available online: https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles

5 on a mass scale will likely be infinitely more complex than moving from level 0 to level 3. Currently there are only level 2/borderline level 3 vehicles available for purchase by the public. Honda has recently indicated it will begin mass producing cars with level 3 autonomy by 2021 for release in Japan (Shibu, 2020). Vehicles with level 3 autonomy will operate without driver assistance if certain conditions are met, however, the driver must be available to take over controls when prompted by the vehicle. Level 3 autonomy represents a potentially dangerous step in the path to full autonomy with some industry leaders vowing to skip level 3 altogether. It represents the transition between "driver assistance" technologies and full autonomy, but still requires the driver to be aware of their surroundings and engaged enough to quickly take controls.

Meanwhile, some industry analysts have doubts that level 5 automation will even be possible:

> "There are basically two camps," says robotics engineer and former Navy fighter pilot Missy Cummings, director of Duke University's Humans and Autonomy Lab. "First are those who understand that full autonomy is not really achievable on any large scale, but are pretending they are still in the game to keep investors happy. Second are those who are in denial and really believe it is going to happen. When you also consider that not everyone is a techie and loves the bells and whistles of advanced systems, I think the automotive industry is in for some tough times ahead." (Adams, 2020)

ADVANCE NOTICE OF PROPOSED RULEMAKING (ANPR) (ANPRM)

On December 3, 2020 the National Highway Traffic Safety Administration (NHTSA) published an ANPR seeking public comment "on the development of a framework for Automated Driving System (ADS) safety." In summary the Agency seeks input on "how to select and design the structure and key elements of a framework and the appropriate administrative mechanisms to achieve the goals of improving safety, mitigating risk, and enabling the development and introduction of new safety innovations." The Montgomery County Planning Department responded to the ANPR with several comments.

There have been major innovations in autonomous sensor technology this decade, however, current artificial intelligence and deep learning approaches "are fundamentally statistical, linking inputs to outputs in ways specified by their training data" (The Economist, 2020) and lack the ability to exhibit intuition and judgment, two fundamental human abilities necessary for safe driving (Adams, 2020). Daily driving is full of "edge cases" that wreak havoc with current autonomous driving intelligence technology. Despite these obstacles, autonomous vehicles have been lauded for their potential to provide numerous societal benefits. McKinsey & Company estimate that if autonomous vehicles were fully adopted, the benefit to the public would exceed $800 billion a year in 2030. A third of this benefit would come from the conversion of land dedicated to parking to more productive land uses, 15 percent of the annual benefit would arise from more productive commuting times, and over half of the benefit would arise from crash avoidance (McKinsey & Company, 2019).

A necessary step in understanding and measuring autonomous vehicle safety is defining exactly what set of environmental conditions the vehicle is designed to operate in. The Operational Design Domain (ODD) is a term that describes the specific operating environments in which the autonomous vehicle is designed to function which may include "roadway types, speed range, lighting conditions, weather conditions, and other operational constraints" (Thorn, Kimmel, and Chaka, 2018). In addition to defining an all-inclusive ODD, additional considerations in a safety framework include Object and Event Detection and Response (OEDR), maneuvers that include other aspects of operation that go beyond controlling vehicle motion itself, and fault management. Together these factors create a "four-dimensional" validation matrix for which "the cross-product space of all possible factors across all four axes must be addressed." The product of this matrix is extraordinarily massive, especially in a built environment as diverse as Montgomery County.

If and when autonomous technology reaches level 5 on a mass scale, increases in safety will also likely be tied to the interplay between full autonomy and allowing for vehicle passengers to make manual "overrides" to the autonomous system. For example, when is it appropriate for a passenger to specify a different speed, path, maneuver, or other operational decision under normal operating environments? Although it has been theorized that level 5 autonomous vehicles will forgo steering wheels and pedals, consumer demand for a manual option may dictate otherwise. A review of the National Motor Vehicle Crash Causation Survey (NMVCCS) indicates there are five categories of driver-related contributing factors to automobile crashes: (1) sensing/perceiving (i.e., not recognizing hazards); (2) predicting (i.e., misjudging behavior of other vehicles); (3) planning/deciding (i.e., poor decision-making behind traffic law adherence and defensive driving); (4) execution/performance (i.e., inappropriate vehicle control); and (5) incapacitation (i.e., alcohol-impaired or otherwise incapacitated driver). Approximately 67 percent of driver caused crashes are due to failures other than sensing/perception errors and incapacitation, two "low-hanging" fruits conceivably addressed by autonomous vehicles. The research illustrates, however, that manual overrides of default decisions made by the autonomous vehicle could result in a substantial number of crashes due to planning/deciding (41 percent), execution/performance (23

MARYLAND'S CONNECTED & AUTOMOATED VEHICLE (CAV) STRATEGIC FRAMEWORK

In 2015, the Maryland Department of Transportation established the Maryland CAV Working Group "as the central point of coordination for the development and deployment of emerging CAV technologies in Maryland". Since 2015, the state has identified several CAV testing sites with numerous public and private pilot programs underway or planned across the state. In 2020, the state adopted the CAV framework after receiving input from 600 survey respondents. The framework is composed of 5 focus areas:

- Public Education and Outreach
- Planning and Policy
- Early Deployment and Testing
- Infrastructure
- Workforce

The framework is intended to support planners implement strategies "to reap the benefits of CAV technology in a safe, efficient, and equitable manner".

percent), and predicting (17 percent) factors (Mueller, Cicchino, and Zuby, 2020).

Some of the equitable concerns related to the safety of vulnerable road users (VRUs) and traffic-safety disparities are based in the technology itself. These concerns should and can be addressed at both the development and pre-deployment stages. There has been growing concern regarding algorithmic bias as it relates to potential disparities in age, skin color, and gender. A handful of studies have emerged highlighting that even the most advanced facial recognition algorithms have difficulty correctly identifying individuals with darker skin tones. Since 2017, the National Institutes of Standards and Technology (NIST) has released studies evaluating facial recognition algorithms from leading artificial intelligence (AI) companies and has repeatedly found that they underperform based on demographic differentials (Simonite, 2019).

To date most studies evaluating the demographic variations of AI performance have focused on facial recognition systems used for law enforcement and national security purposes. However, these findings can help inform what additional gaps exist in the AV technology and provide recommended avenues of research to mitigate demographic differentials that can improve the reliability of pedestrian identification and perception. Currently, we have only identified one study that examines predictive disparities of machine learning as it relates to AV perception applications. Researchers at the Georgia Institute of Technology found that the discrepancies in detecting pedestrians with darker skin tones on the Fitzpatrick skin type scale (4-6) could not be attributed to challenges related to pedestrian detection, such as time of day, occlusion, varied lighting conditions, or clothing. The study suggests that one cause of disparities is sampling bias, which distorted the model's behavior by prioritizing accuracy for the larger population group, pedestrians with lighter skin tones (1-3). The researchers found that reweighting could correct the impacts of function loss prioritization in standard datasets, which they found overrepresented lower-Fitzpatrick (1-3) scored pedestrians by a factor three (Wilson, Hoffman, and Morgenstern, 2019).

Aside from the potential societal and equity impacts noted above, there have been modeling attempts to estimate autonomous vehicle market penetration and impacts to other transportation metrics. It is presumed by many transportation planners that autonomous vehicles have the potential to increase vehicle miles travelled (VMT) due to a decrease in the cost of travel, but decrease overall delay due to operational efficiencies (Figure 9). These assumptions, however, entirely depend on the ownership makeup (shared vs. private) of the autonomous vehicle fleet. One analysis conducted by a large bank and investment corporation takes an optimistic view regarding the potential cost savings of "robotaxis" by concluding that for "people living in cities, robotaxis could offer a far cheaper and more convenient alternative to car ownership"(The Economist, 2018).

At the moment, travelling by Uber or another ride-hailing service costs around $2.50 a mile; but take away the driver, and that cost could fall to $0.70 a mile," which is comparable or slightly cheaper than existing car ownership costs (The Economist, 2018). The CEO of a prominent electric car manufacturer pontificated that robotaxis "would [cost less than] than 18 cents per mile," well below the cost of a traditional private automobile (Boyle, 2019). It is unclear, however, whether this estimate includes the necessary margins to produce an acceptable profit. One of the most bullish analyses conducted to date estimates that robotaxis "will offer vastly lower-cost transport alternatives — four to ten times cheaper per mile than buying a new car and two to four times cheaper than operating an existing vehicle in 2021" (Arbib and Tony Seba, 2017). An academic analysis, however, conducted by researchers at MIT in the San Francisco, California area found that conventionally driven vehicles' "total cost of ownership is a remarkably low 72 cents per mile, whereas the high licensing, insurance, cleaning and safety oversight costs associated with autonomous taxis combined with the low (52 percent) utilization rate of the current taxi fleet means robotaxis are likely to cost between $1.58 and $6.01 per mile (Neidermeyer, 2019). This analysis, however, assumes existing costs and vehicle occupancy rates to persist into the future, including a $250,000 taxi medallion fee which may not be reasonable.

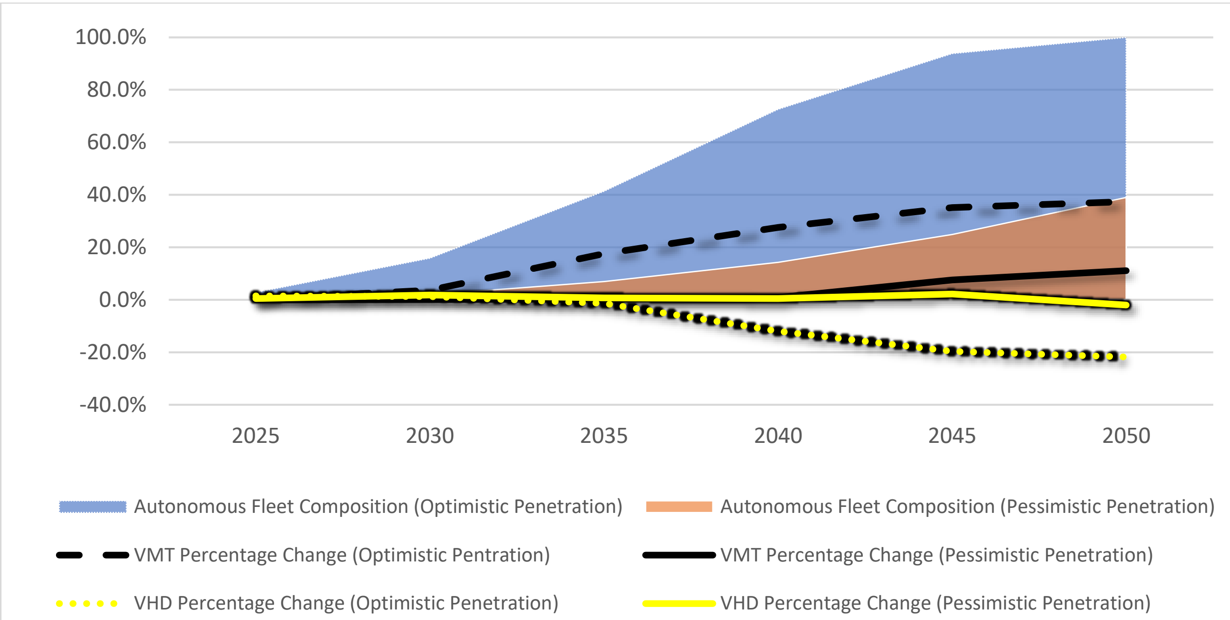


Figure 9: Estimated AV Market Penetration and Baseline (no AV Market Penetration) Changes in Vehicle Miles Traveled (VMT) and Vehicle Hours of Delay (VHD)[8]

Despite the many obstacles in reaching level 4 and 5 autonomy, progress is being achieved. Several dozen ride-hailing companies are test driving vehicles in California, Arizona, and Nevada. In California, companies operating autonomous vehicles are required to log and submit the number of miles driven and "how often their vehicles disengaged from autonomous mode during tests" (California Department of Motor Vehicles, 2021). In 2020, there were more than 1.9 million miles of supervised autonomous driving reported in California led by Cruise and Waymo. A total of 3,695 disengagements were reported for an average of approximately 529 miles per disengagement (it is unclear if an objective has been set). A disengagement can occur due to technology failure or situations requiring the test driver to take manual control of the vehicle to operate safely. California has also recently provided a process for ride hailing companies to charge fees for autonomous taxi rides (pending a lengthy approval process). In Phoenix, Arizona, Waymo is now providing level 4 autonomy to customers in a "in a 50-square-mile area in the suburbs of Chandler, Tempe, and Mesa" (Crowe, 2020). Motional and Lyft, who completed 100,000 supervised paid self-driving taxi rides in Las Vegas since 2018, recently announced plans to launch "fully driverless robotaxi services in major U.S. cities in 2023" (Korosec, 2020).

[8] Estimated using AECOM's Mobilitics Platform for the Washington, DC Area. Mobilitics is a scenario-based planning tool to estimate the impacts of autonomous vehicles. Available online: http://mobilitics.aecom.com/Home/MainConsole/8

The next five to 10 years will likely see a rapid increase in autonomous e-hailing services offered in select areas of the country (level 4 autonomy). The trucking industry could also see a rapid adoption of platooning. Platooning occurs when a manned truck is followed by several autonomous vehicles that travel between major distribution hubs.

The federal government will likely be playing catch up over the next few years with regard to autonomous oversight and safety standards. NHTSA has begun the process of defining its autonomous safety requirements. It is also important that local governments play an active role in their autonomous future. There will likely be numerous local implications and impacts to revenue streams, infrastructure (including 5G deployment), data collection and privacy concerns, zoning (curbside management and parking), intra-agency coordination, transportation adequacy determination, equity issues, and procurement. Local governments have an opportunity to partner with state agencies to transform major corridors into hubs of innovation (including autonomous transit technologies) and explore other autonomous pilot opportunities. The American Planning Association (APA) says "the time to begin planning [for autonomous vehicles] is now" via community stakeholder engagement, comprehensive and function plans, regulations, standards and incentives, and site design and development review (Hanagan, 2018). If local governments do not begin to proactively plan for an autonomous vehicle future, they may be forced to deal with the consequences via reactive policy making.

Connected Vehicles and Infrastructure

Connected vehicles (CV) possess the ability to transmit and share telemetry and other data with infrastructure and other nearby vehicles. Data transmission is two-way and often expressed in terms of three categories (Gettman, 2020):

- V2V: vehicle-to-vehicle
- V2I: vehicle-to-infrastructure
- V2X: vehicle-to-everything, including vulnerable road users, such as cyclists and pedestrians

V2V, V2I, and V2X should not be confused with other connected technologies that vehicles are now outfitted with. Many newer models can connect to cellular networks, Wi-Fi, and global positioning systems (GPS) mainly for infotainment and navigation purposes. Connected technologies that

APA'S AV PLANNING "QUICK WINS"

- Brief county council on need to communicate priority for preparing for transportation technology.
- Develop a fact sheet on existing and trending transportation technology (shared-use mobility, mobile apps).
- Develop a common transportation technology lexicon.
- Work with local news outlets to run a series on mobility of the future.
- Identify likely "hot topics" with the public (e.g., safety, costs, equity).
- Audit a recently completed plan as if transportation technology were included in the scope to identify changes.
- For plans under development, insert a minimal statement on planning for autonomous cars into a current planning process or an out-of-cycle plan amendment.
- Develop a short add-on task to existing contracts to examine codes/plans and make recommendations for near- and medium-term action.

support VSV, V2I and V2X require a much lower latency than traditional cellular networks. The Federal Communications Commission (FCC) has reserved the 5.9 GHz band, known as the "Safety Band," for vehicle and infrastructure communications (Furchtgott-Roth, 2021). At the end of the Obama administration, the NHTSA was on the cusp of mandating that all vehicles be outfitted with Dedicated Short Range Communications (DSRC) technology. The proposed rulemaking was never enacted, however, and support for the technology may be waning. In November of 2020, the FCC voted to "split the 75 megahertz of formerly-DSRC spectrum at 5.850-5.925 GHz, allocating the lower 45 megahertz of the band for unlicensed use and the upper 30 megahertz for intelligent transportation systems" (Hill, 2020). There is also a competing radio technology to DSRC called cellular vehicle-to-everything (C-V2X). For clarity, the "cellular" use in this context does not refer to the use of cellular networks, but rather the use of the underlying electronics in cellular radios adapted to communicate from one radio directly to another" (Gettman, 2020). Unfortunately, C-V2X and DSRC are not interoperable and devices cannot communicate with one another. Ford recently announced that it will be deploying C-V2X technology on all of its new cars starting in 2022 (Stevens, 2019). This may provide the necessary momentum to spur industrywide adoption of the technology.

Regardless of the type of communication technology employed, NHTSA estimates that 615,000 crashes and 1,366 deaths could be avoided each year if connected vehicle technology was ubiquitous (NHTSA, 2020). Although mass production of these technologies has been limited, the United States Department of Transportation, through its Intelligent Systems Joint Program Office (ITS JPO), has provided millions of dollars in grants to deploy various connected technology pilots (mostly using DSRC) across the United States. ITS JPO provides numerous applications of connected technologies. It should be acknowledged that signal priority for transit has been implemented, albeit using different technology, along the US 29 FLASH BRT corridor in Montgomery County.

V2V	V2I	V2X
• Emergency Electronic Brake Lights (EEBL) • Forward Collision Warning (FCW) • Intersection Movement Assist (IMA) • Left Turn Assist (LTA) • Blind Spot/Lane Change Warning (BSW/LCW) • Do Not Pass Warning (DNPW) • Vehicle Turning Right in Front of Bus Warning (Transit) • Queue Warning (Q-WARN) • Dynamic Speed Harmonization (SPD-HARM) • Cooperative Adaptive Cruise Control (CACC)	• Red Light Violation Warning • Curve Speed Warning • Stop Sign Gap Assist • Spot Weather Impact Warning • Reduced Speed/Work Zone Warning • Pedestrian in Signalized Crosswalk Warning (Transit) • (transit, freight) • Emergency Vehicle Preemption (PREEMPT)	• Advanced Traveler Information System • Intelligent Traffic Signal System (I-SIG) • Mobile Accessible Pedestrian Signal System (PED-SIG) • Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG) • Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE) • Emergency Communications and Evacuation (EVAC) • Transit Connection Protection (T-CONNECT) • Dynamic Transit Operations (T-DISP) • Dynamic Ridesharing (D-RIDE)

Table 1: Sample of Connected Vehicle Applications

USDOT's Accessible Transportation Technologies Research Initiative (ATTRI) "is leading efforts to develop and implement transformative applications to improve mobility options for all travelers, particularly those with disabilities" (USDOT, 2021). The hypothetical fully actuated MaaS themed "complete trip" illustrates how autonomous and connected technologies can complement one another to assist a disabled traveler with their trip to a coffee shop (Figure 10). Obviously, this hypothetical situation will require several years, if not decades, of technological maturation, however, it illustrates the promise that these disruptive technologies can provide.

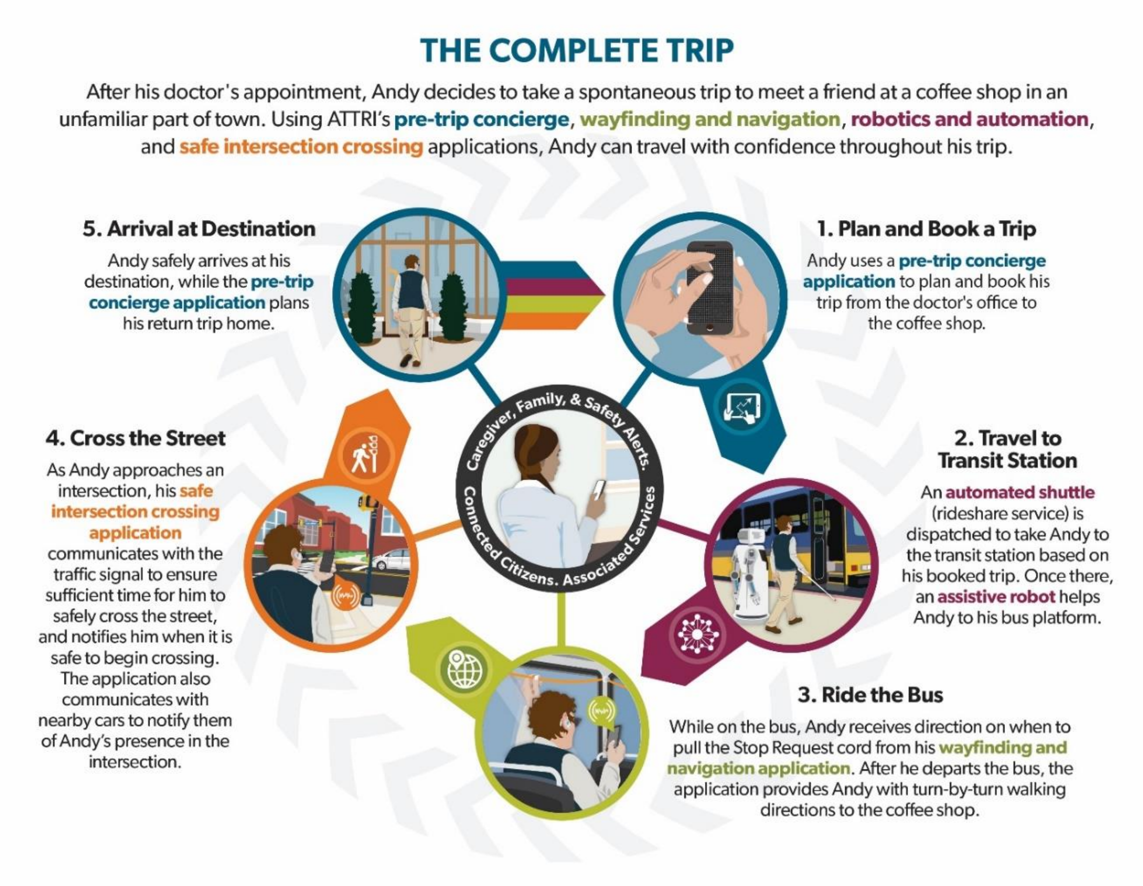


Figure 10: An illustration of how autonomous and connected technologies may someday facilitate "the complete trip" for visual impaired individuals in a MaaS environment[9]

Alternative Fuel Vehicles

According to the United States Department of Energy (DOE), there are more than a dozen alternative fuels in production or under development for use in vehicles (DOE, 2020) with the most popular being:

- Biodiesel
- Hydrogen
- Electricity
- Ethanol
- Natural Gas
- Propane

[9] https://www.its.dot.gov/research_archives/attri/images/attri_completetrip.jpg

Electrification has gained the most traction in the alternative fuels arena over the past decade and appears primed to continue to make larger penetrations into the market. As of January 2021, California, Massachusetts, and New Jersey have banned the sale of combustion engines by 2035.

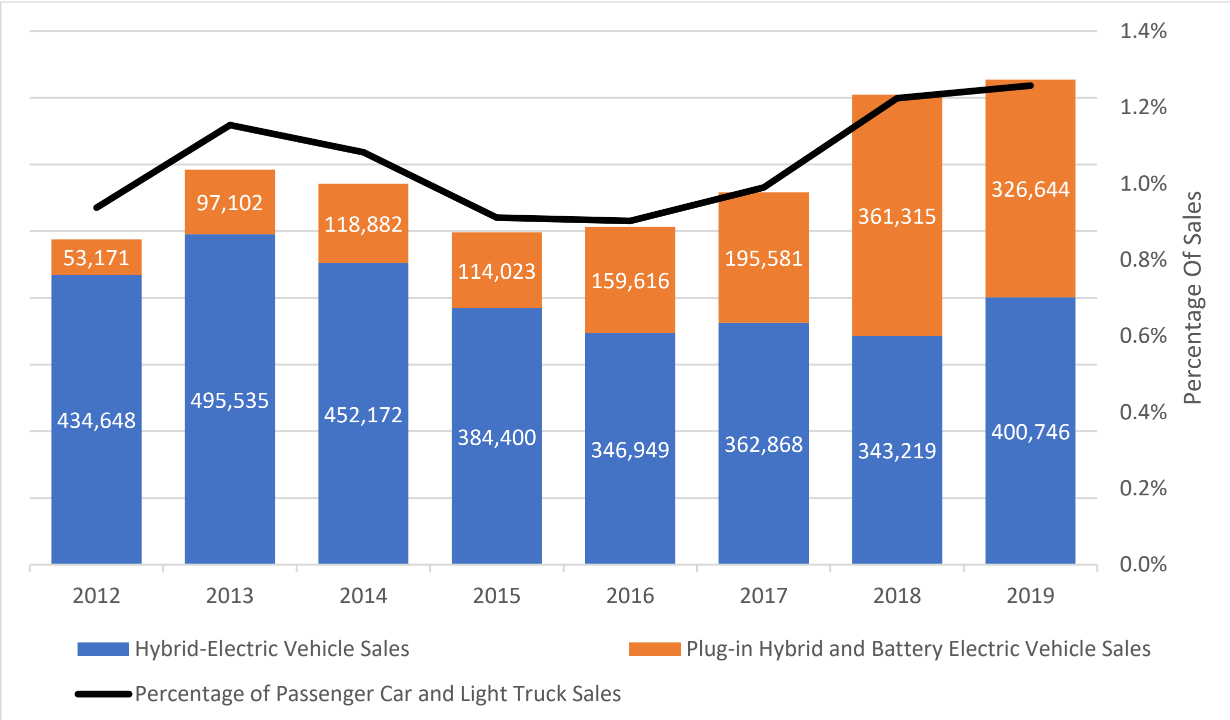


Figure 11: Hybrid-Electric and Plug-In Electric Sales in the United States[10] [11]

"Currently available electric-drive vehicles (EDV) in the U.S market include hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV), battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV)" (Argonne National Laboratory, 2021). BEV sales in the U.S. jumped by approximately 85 percent between 2017 and 2018 but saw a slight decrease in 2019. Decreases in gasoline fuel costs and the phasing-out of federal tax credits for popular models are partly to blame for this decrease. Sales likely decreased even more in 2020 in large part due to the COVID-19 pandemic. According to a recent nationwide survey conducted by *Consumer Reports*, the three major deterrents to purchasing a plug-in electric vehicle are not enough public charging stations, purchase price, and insufficient driving range (Consumer Reports, 2020). In Montgomery County, PHEVs and BEVs represented approximately 1.2 percent of all vehicle registrations at the end of FY 2020.

Worldwide, automakers launched 143 new electric vehicles in 2019 and plan to introduce around 450 additional models by 2022 (Gersdorf, Hertzke, Schaufuss, and Schenk, 2020). Market efficiencies as well as new entrants into the electric vehicle market are expected to drive down prices. Battery technology is rapidly evolving and industry experts believe a new "solid-state" battery concept will be available by

[10] Alternative fuel sales from Department of Energy, 2021. Alternative Fuels Data Center. Retrieved from https://afdc.energy.gov/data/ on February 26, 2021

[11] Total passenger vehicle sales from Bureau of Transportation Statistics, 2021. New and Used Passenger Car and Light Truck Sales and Leases. Retrieved from https://www.bts.gov/content/new-and-used-passenger-car-sales-and-leases-thousands-vehicles on February 26, 2021.

2024 that will substantially increase the range of electric vehicles and reduce the necessary charging time. Electric vehicles are also getting cleaner in large part due to the diversification of the country's grid supply. Just eight years ago, "less than half the people in the United States lived in a region where the average EDV produced less emissions than a gasoline car with a fuel economy rating of 50 mpg—today nearly everyone does" (Reichmuth, 2020). According to the Union of Concerned Scientists, the "average electric vehicle" charged in our region produces global warming pollution equal to a gasoline vehicle that gets 87 miles per gallon. Despite these positive developments, Deloitte estimates that without drastic policy interventions, the EDV share of new car shares in the United States will just be 27 percent in 2030 (Woodward, et al., 2020). The Electric Power Research Institute's medium forecast estimates EDV's share of new car sales to just be 12 percent making up a paltry five percent of the total light duty fleet in 2030 (McConnell and Leard, 2020).

These sobering estimates illustrate the slow rate at which vehicle fleets turn over. For example in 2018, approximately half of the light-duty vehicle fleet in the Washington, DC area was more than eight years old (Figure 12). These estimates do not even consider the medium and heavy trucking sector which will likely take even longer to decarbonize, although the public sector can play a big role. For example, the Montgomery County Public School System recently announced plans to fully electrify its fleet by 2035. These future projections also assume households will continue to own vehicles at the same rate as today. If a MaaS platform is successful at delivering an on demand, safe, cheap, and reliable mobility service, car ownership rates may precipitously fall, particularly in urban areas. RethinkX estimates that robotaxis would be used 10 times more than individually owned vehicles, greatly reducing the number of cars needed to be retired and replaced with electric vehicles (Arbib and Tony Seba).

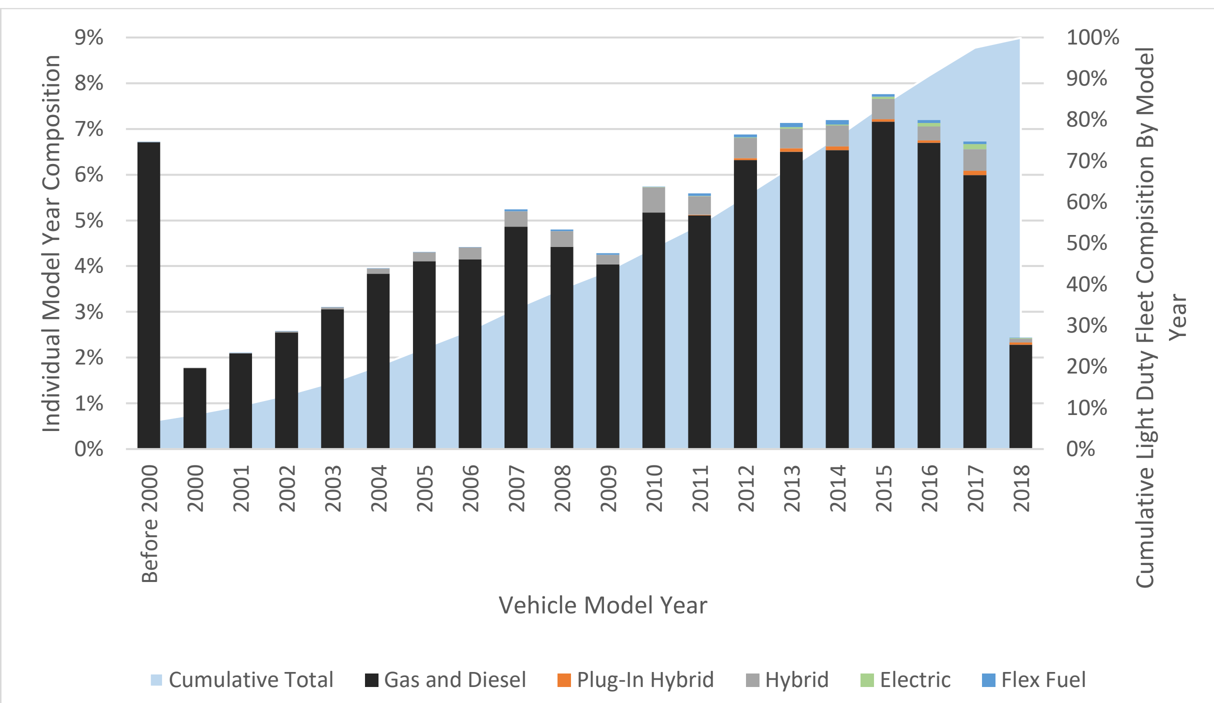


Figure 12: Composition of Passenger Vehicle Fuel Types by Model Year in 2018 in the Washington D.C. Region[12]

[12] Washington Council of Governments (2021). 2017/2018 Regional Travel Survey Public Files.

One other alternative fuel source that could gain momentum and should not be discounted is hydrogen. Hydrogen refueling can "fuel up relatively quickly—about 15 times faster than battery-powered EVs that use so-called fast-charging technology" and requires half the capital investments as EV fast charging stations (Heid, Linder, and Wilthaner, 2019). Hydrogen also has more energy per unit mass than gasoline which is important for larger vehicle applications such as passenger jets and semi-tractor-trailer trucks. Although hydrogen is the most abundant element in the universe, on Earth, it must be separated from other compounds. Often, these compounds are fossil fuels such as natural gas and the extraction process leads to GHG emissions. The concept of green hydrogen is gaining momentum as advancements in electrolysis techniques (separating hydrogen from water using clean electricity) become more efficient and cost effective. Scientists are also studying if the process of photosynthesis can be mimicked to produce hydrogen from sunlight and water. Current scale and catalyst material limitations prevent this technology from being economically feasible, but there is optimism that these barriers can be overcome. If so, green hydrogen could play a major role in the decarbonizing of the economy beyond the transportation sector. Still, due to infrastructure limitations and time necessary for technology maturity, we are likely decades away from seeing mass adoption of hydrogen-based fuels.

Conclusion

American futurist Roy Amara once said that "we tend to overestimate the impact of a new technology in the short run, but we underestimate it in the long run" (Ridley, 2017). Undoubtedly there has been short term hype around emerging technologies in the transportation sector. Many of these technologies have many years of maturity ahead. It is also clear, however, that progress is being made and now is the time to begin planning. Fully autonomous robotaxis are now roaming the streets of Phoenix and Las Vegas. California has just released an approval process for companies to do the same. Tesla has just announced it is releasing its "fully-autonomous" subscription service during the second quarter of 2021. The federal government has begun its rule making process to evaluate the safety of autonomous vehicles. We may be reaching an inflection point for rapid adoption of some of these technologies.

LEGISLATION WATCH

Growing Renewable Energy and Efficiency Now (GREEN) Act of 2021

The Federal Government has had a long standing tax credit of up to $7,500 for purchases of new PHEV and BEVs. The program, however, put a cap of 200,000 vehicles per manufacturer. Tesla and General Motors have since exhausted their available credits. The GREEN Act, introduced on February 5, 2021 would decrease the maximum credit by $500 but increase the manufacture's cap to 400,000 vehicles.

Electric Cars Act

Introduced on February 23, 202e1, the Electric Cars Act would:

- Eliminate the manufacturer electric vehicle tax credit cap
- Allow buyers to use the tax credit over a 5-year period, or apply the credit on the spot at the dealership
- Extend the Alternative Fuel Vehicle Refueling Property Tax Credit by 10 years

If properly managed through price controls and other policies, autonomous and electric/fuel cell vehicles and micromobility could provide a catalyst for a successful MaaS platform that expands mobility opportunities to disadvantaged communities while helping the county meet its GHG reduction goals. Proactive planning in the context of Thrive Montgomery 2050's overarching outcomes: economic health, equity, and environmental resilience will be necessary. Montgomery County should look to these early adopters for lessons learned and opportunities to participate in pilots via grants such as USDOT's Smart City Challenge initiated in 2015. The state of Maryland has developed a framework to assist local governments with their CAV planning strategies. Fairfax County has launched Virginia's first publicly funded autonomous electric shuttle pilot project in the Mosaic District. The pilot project is a "public-private partnership between Fairfax County, Dominion Energy, EDENS (Mosaic District developer), Virginia Department of Rail and Public Transportation, Virginia Department of Transportation, Virginia Tech Transportation Institute, and George Mason University" (Fairfax County, 2021). Emerging and disruptive technologies will present Montgomery County with challenges and opportunities, but they should not be dismissed as unrealistic or "too far into the future." Industry driven investments will create demand where none previously existed, and the county should be prepared.