Resilience 2050
Adapting to the Challenges of Tomorrow

White Papers
Issue 6 - September 2022

Emerging Technologies

Part I - Mobility on Demand and Micromobility
Part II - Vehicle Technologies

This white paper provides an overview of recent and expected advances in transportation technologies across a range of modes, including cars, freight carriers, public transit and micromobility vehicles. With the rise of Electric Vehicles, Advanced Driver Assistance Systems, Connected Vehicles and Automated Vehicles, there is potential to reimagine transportation systems in the Baltimore region. The BRTB is preparing for these rapid technological advances while staying true to its mission and goals to make investment decisions and develop programs and projects that support a safe, efficient, accessible, equitable and environmentally-responsible transportation system for all users.

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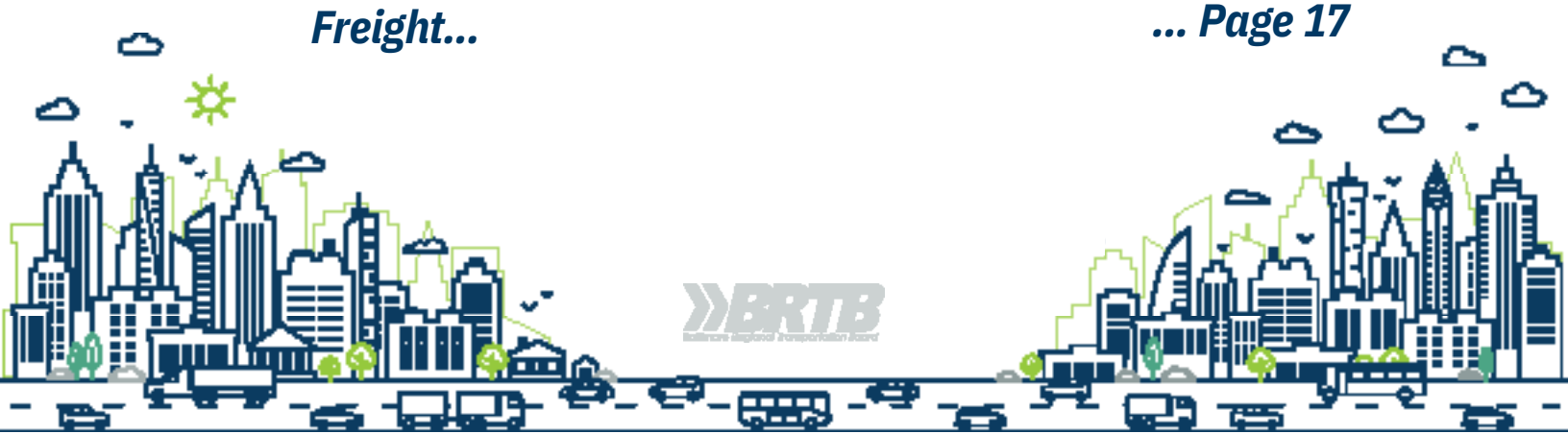

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Overview of Mobility on Demand and Micromobility

Many people are endlessly fascinated by technology. Others are confused or frustrated. We frequently encounter an alphabet soup of terms, a mix of "platforms," lengthy operating instructions, multi-character passwords and notoriously long license agreements. Transportation terms can be equally confusing, and describing emerging technologies in transportation can be a difficult task. This paper seeks to cut through the jargon and outline some of the key technologies emerging in the region and across the country.

The paper begins with an enabling technology, **Mobility as a Service (MaaS) and Mobility on Demand (MOD)**, and also discusses **micromobility** in the Baltimore region.

MaaS and MOD are innovative transportation concepts where consumers can access mobility, goods and services on-demand by dispatching or using ride-sourcing from a variety of providers including:

- transportation network companies (TNCs) such as Uber and Lyft
- e-scooter and e-bike sharing
- microtransit
- shuttle services
- public transportation
- courier network services (CNS) and personal delivery devices (PDD) and other automated delivery services, and
- connected and automated vehicles (CAV/AV).

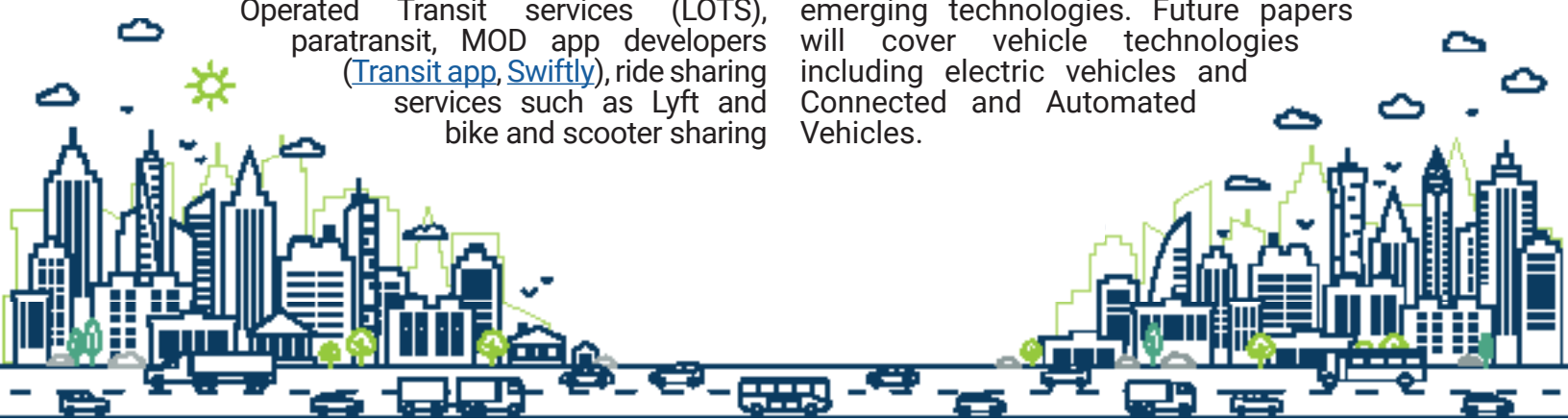
The Maryland Department of Transportation Maryland Transit Administration has begun to organize a wide array of mobility providers including their transit services, Locally Operated Transit services (LOTS), paratransit, MOD app developers (Transit app, Swiftly), ride sharing services such as Lyft and bike and scooter sharing services. Ultimately, the goal of partnering on MOD is to harness the positive impacts (e.g. increased accessibility, reduced travel costs), reduce single-occupant vehicle travel and shift travel behavior in a way that helps more equitably distribute resources, reduce congestion and improve air quality and the environment.

Reaching the full potential of MOD involves coordinating with a variety of modal operators, both public and private, and will require complex and careful integration. Other challenges include equity concerns, security and privacy, protecting public safety, data ownership and regulations.

Micromobility is another key emerging technology in the region. The Federal Highway Administration used the Society of Automotive Engineers International's Taxonomy and Classification of Powered Micromobility Vehicles to broadly define micromobility as "any small, low-speed, human- or electric-powered transportation device, including bicycles, scooters, electric-assist bicycles, electric scooters (e-scooters), and other small, lightweight, wheeled conveyances."

Baltimore City has the largest set of micromobility services in the region. The Baltimore City Department of Transportation has a growing track record of success since the launch of their dockless vehicle program in 2019 and offers an array of best practices for others. Their annual permit program has seen stiff competition, with an impressive pre-COVID ridership peak of over 76,000 weekly trips in September of 2019. When COVID-19 struck in March 2020, ridership initially dropped by more than half, and is slowly recovering.

Read this paper to learn more about these emerging technologies. Future papers will cover vehicle technologies including electric vehicles and Connected and Automated Vehicles.



Emerging Technologies: Mobility on Demand and Micromobility

Mobility on Demand (MOD)

Many people are endlessly fascinated by technology. Others are confused or frustrated. We frequently encounter an alphabet soup of terms, a mix of "platforms," lengthy operating instructions, multi-character passwords and notoriously long license agreements. Transportation terms can be equally confusing, and describing emerging technologies in transportation can be a difficult task. This paper seeks to cut through the jargon and outline some of the key technologies emerging in the region and across the country, starting with an enabling technology, **Mobility as a Service (MaaS)** and **Mobility on Demand (MOD)**.

In a recent report from the World Bank, researchers described the differences behind these two very similar and significant emerging technology concepts in this way:

"In Europe and North America, two complementary approaches to integrated mobility and multimodal access to public and private transportation services are evolving in parallel. In the United States and Canada, consumers are assigning economic values to transportation services and making mobility decisions (including the decision not to travel and instead have goods delivered) based on cost, travel and wait time, number of connections, convenience, and other attributes — a concept commonly referred to as Mobility on Demand (MOD). In Europe, services that allow travelers to sign up for mobility services in one bundle are gaining popularity — a concept known as Mobility as a Service (MaaS)." (Shaheen 2021)

MaaS and MOD are innovative transportation concepts where consumers can access mobility, goods and services on demand by dispatching or using ride-sourcing from a variety of providers including:

- transportation network companies (TNCs) such as Uber and Lyft,
- e-scooter and e-bike sharing,
- microtransit,
- shuttle services,
- public transportation,
- courier network services (CNS) and personal delivery devices (PDD) and other automated delivery services and
- connected and automated vehicles (CAV/AV).

Mobility as a Service (MaaS) and Mobility on Demand (MOD) are sometimes used interchangeably. However, they are different. The difference is subtle and lies in how these services are offered and monetized and how these services aggregate and unite travelers. The differences are important and may matter to the end user. Specifically, MaaS creates a definitive set of travel options for a fee, typically offered as a "subscription" available from a smartphone or other internet enabled device. In much the same way as Netflix and Spotify provide access to TV,

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movies and music, MaaS provides access to a described set of transportation options via the internet. Service providers could be a public or private entity, but in concept MaaS offers end-users access to mobility options through a single application and a single payment channel (instead of individual and separate ticketing and payment operations typical in any market today).

Similarly, MOD typically offers access to multiple service providers (public and private) through a single point from a smart device. Unlike MaaS, it can be requested in a variety of ways. MOD is typically made available through a web browser (smart device, computer, etc.), a call center or telephone service, direct cash payment options at a store, hub or other facility, at digital kiosks and via non-technology-based access (such as street hailing, e.g. the "finger shake"). Broad availability helps address challenges of accessibility and equity of the services being provided, especially for people without access to a smartphone, people with vision impairments, people who require non-English communication and others. It should be noted that MOD is not a new concept, but recent technological advancements have facilitated these services and their deployment in new, easier and unique ways. The United States Department of Transportation (USDOT) regards MOD as a broader and preferred term (to MaaS) for the reasons outlined above so that is the term we have adopted.

MOD at MDOT MTA

MOD technology provides an opportunity for public transit operators by placing them at the center of the mobility ecosystem and empowering them to lead in structuring and organizing the transportation network. MOD could serve as a key tool to organize an array of services for the traveling public and to support other societal and policy goals, such as the successful deployment of multimodal solutions that make it easier for residents, businesses and visitors to utilize sustainable, shared and public transit services of the ecosystem. Fortunately, this hasn't gone unnoticed by Maryland Department of Transportation Maryland Transit Administration (MDOT MTA). MDOT MTA is the primary public transit provider in the Baltimore region, particularly in the densest parts of the region. As such, within the Baltimore regional mobility ecosystem, MDOT MTA has a vested interest in the successful pairing of public transit with the shared mobility that MOD technologies enable.

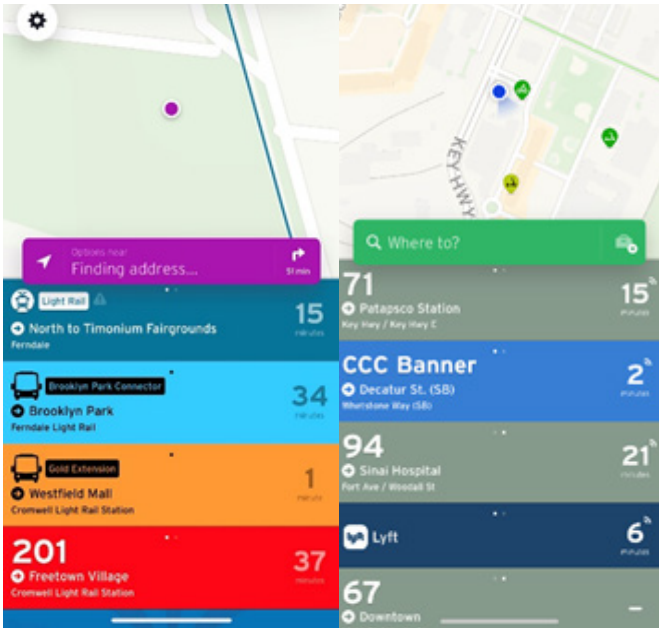
MDOT MTA has begun to organize a wide array of mobility providers including their transit services, Locally Operated Transit services (LOTS), paratransit, MOD app developers (Transit app, Swiftly), ride sharing services such as Lyft and bike and scooter sharing services. Together these "partners" have created a network for the region. This network is often described as a shared mobility "ecosystem" of transportation resources. Supporting MOD has numerous potential mutual benefits for partner organizations (public and private), such as reducing parking demand, decreasing partner costs, and achieving environmental goals. Ultimately, the goal of partnering on MOD is to harness the positive impacts (e.g. increased accessibility, reduced travel costs), reduce single-occupant vehicle travel and shift travel behavior in a way that helps more equitably distribute resources, reduce congestion and improve air quality and the environment.

MDOT MTA, LOTS and others in the region are quietly and boldly leading the way. MDOT MTA's Shared Mobility Work Plan 2020 created a path to improving access to shared mobility across the region and the state,

using the region's transit system as the foundation. In 2018, MDOT MTA piloted a real-time information service for bus routes. Swiftly GPS units were installed on MDOT MTA buses and Transit, a real-time information mobile app, was launched. The Transit application offers a sophisticated trip planner that aggregates a range of mobility options online to users. Users can get information about a variety of services available in their vicinity to get them to their intended destination. Directions on the app can combine a variety of modes such as a bus with the light rail with an e-scooter or bike-share or car-share service. Users are offered information on the best route including various modes, alternative routes and the timing and cost for travel to their destination.

MDOT MTA and several of the LOTS (Annapolis Transit, Carroll Transit, Charm City Transit, County Transit – Queen Anne's County, Harford Transit and RTA Central Maryland) have made this possible by making their schedule and real time information data available for use by software developers and encouraging innovation in a variety of software applications. MDOT MTA uses its in-house technical expertise to develop the General Transit Feed Specification (GTFS) and has been working closely with Swiftly and Transit app. These code developers and designers have created MOD internet applications for smartphones that benefit transit agencies and riders.

App developers utilize GTFS "feeds" that include information such as fixed-route schedules, routes and bus stop data. GTFS datasets are used in a variety of types of applications, including trip planners such as Google Maps, mobile applications, timetable generation software, tools for transit planning and operations analysis and other categories of applications. GTFS datasets for MDOT MTA's core service (i.e. local bus, Light RailLink and Metro SubwayLink) include data on fare charges for these services to enhance transit riders' decision-making and travel choices. MDOT MTA is working toward providing fare data for MARC Train and Commuter Bus, and hopes it will be added in the near future. Serving up this information online could enable software developers to provide more vital information to MDOT MTA customers. Real time GTFS data for local bus service (CityLink, LocalLink and Express BusLink) and Commuter Bus service is currently available through Swiftly API's. MDOT MTA static schedule data is updated frequently, and real time information is updated every 30 seconds. In June 2020, MDOT MTA disaggregated its GTFS data into separate mode-specific filesets instead of



one large GTFS file for all scheduled service. This allowed for more specific and accurate service and trip planning.

As MDOT MTA works to improve the application, they hope to include diversion and improved delay (disruption) information along with arrival information. A longer-term goal is to include fare integration so the traveler can easily and conveniently pay for travel on a single platform. However, working out the details of this arrangement will be challenging (discussed further below). The end goal is to get reliable and understandable information to customers quickly so they can make the best decisions for themselves. MDOT MTA also expects to better utilize its existing infrastructure, such as their digital signs and other prior investments, to improve customer experience.

At the local level, Anne Arundel County has partnered with Transit app to offer their premium product "Royale" free to their system users. This offers improved trip planning options for users to better plan their routes and utilize a variety of services.

A Challenge and an Opportunity

Coordinating all of this information and offering it to the public in a safe, reliable and timely manner is central to getting MOD right. Fully reaching the potential of MOD will require complex and careful integration as it involves coordinating with a variety of modal operators, both public and private. Coordination challenges include:

- working with a variety of modal operators, their services and their assets to cooperatively design, implement and manage payment systems,
- managing curb and lane space in public and private rights-of-way,
- coordination of land use and transportation policies as well as the regulation and enforcement of rules,
- potential legal challenges such as redefining or limiting legal responsibilities and authorities and the rights to assets that support operations,
- establishing and collecting fares, fees (gratuities) and fines and
- other challenges that may not yet be known.

Partnerships around these functions already exist in various ways, but the continued growth of shared mobility and the public's increasing adoption of technology has highlighted the need for closer coordination. Existing partnerships must be leveraged and expanded to establish new ways to achieve the region's collective goals and seize opportunities to affect change on regional mobility.

Known MOD Challenges & Potential Remedies

- **Equity** – MOD should enhance mobility, access and economic opportunity for all travelers, but it can raise equity concerns. Policies and regulations should address an array of equity issues, such as ensuring access for people with disabilities, unbanked and underbanked users and people without access to smartphones or the mobile internet.

- **Standardizing technologies** – Security, privacy and open data standards could accelerate or stall the pace of MOD growth and support multimodal integration.

- **Historically challenged transit deserts** – MOD may present a unique opportunity to enhance mobility and access to areas where services have remained a challenge (e.g. low-income areas, low-density communities, older adults or people with disabilities).

- **Public safety** – Balancing operating needs of private sector services and the need to protect the public may require a close evaluation of current policies and regulations that inhibit market entry, define or limit geographic coverage, extent of service and service quality for traditional and innovative forms of MOD.

- **Data ownership** – Who owns the data and to what extent is privacy of information of the user protected? To what extent could emergency services at local, state and federal levels have access?

- **Legislation and regulation** – This can play a notable role in safeguarding transportation equity by mitigating emerging MOD technological and access barriers, although more research and policy guidance is needed to clarify the applicability and scope of existing statutes.

MOD Programs within the USDOT and Other Agencies

There are many ongoing programs contributing to the USDOT's vision of MOD. These initiatives have focused on specific aspects of MOD, such as technology, data-centric transportation integration, operations and management, policy and standards and pilot programs.

For MOD programs to grow and evolve, it is critical to have close collaboration with key initiatives including but not limited to Integrated Corridor Management, Active Transportation and Demand Management (ATDM), Mobility Services for All Americans (MSAA), MOD Sandbox and Accessible Transportation Technologies Research Initiative (ATTRI) Programs. Moreover, close collaboration with other federal agencies, including the Department of Energy, Department of Defense, Department of Labor and others will be instrumental to advancing the USDOT's MOD Program.

MOD and Resilience 2050

Technologies are constantly changing and there remains a significant amount of uncertainty surrounding the impact of emerging technologies, particularly MOD. As use of these emerging technologies becomes more widespread, the BRTB will continue to monitor potential risks and impacts and identify actions to take. Understanding the potential and consequences of technologies is important to help to ensure the region harnesses the positive effects of technology and avoids or minimizes potential negative effects.

Micromobility in the Baltimore Region

Another emerging technology that has become important to the region is Micromobility. Micromobility is the use of small, fully or partially human-powered vehicles such as bikes, e-bikes and e-scooters for typically short distance travel purposes. The Federal Highway Administration used the Society of Automotive Engineers International's Taxonomy and Classification of Powered Micromobility Vehicles to broadly define micromobility as "any small, low-speed, human- or electric-powered transportation device, including bicycles, scooters, electric-assist bicycles, electric scooters (e-scooters), and other small, lightweight, wheeled conveyances."

Private companies, taking advantage of recent innovations in battery and vehicle design, have increased their availability to the general public via shared-use fleets. These companies offer a service that has proved a popular transportation option as an alternative mode for short trips. These vehicles are generally rented through a mobile app or kiosk, and are "dockless", meaning they are picked up and dropped off in the public right-of-way. State and local laws govern operations of these services and each continuously monitor and respond to emerging technologies in order to protect the public interest, adapt to and take advantage of how these technologies are reshaping the mobility choices of our residents and businesses.

Baltimore City has the largest set of micromobility services in the region and warrants a closer examination. The Baltimore City Department of Transportation (BCDOT) has a growing track record of success since the launch of its dockless vehicle program in 2019, and offers an array of best practices for others. Their annual permit program has seen stiff competition and saw an impressive pre-COVID ridership high of over 76,000 weekly trips in September of 2019.

The Baltimore City Department of Transportation has a growing track record of success since the launch of its dockless vehicle program in 2019, and offers an array of best practices for others.

Program Design

The City's program has a set of deliberate goals it desires to achieve in order to permit service. Strict program requirements carry the risk of constraining the private sector response. The City was careful to negotiate with and onboard private service operators in an effort to enable them to provide services to address the City's needs.

One important service goal was a deliberate effort to enable equitable access to vehicles across Baltimore City's neighborhoods. To do this, the City manages each operators' total number, type and placement of vehicles by closely monitoring vehicle distribution and operation of the service. Unique technology helps to ensure program requirements are

Yeison Muñoz tests out a new seated scooter in Federal Hill. Superpedestrian, a transportation robotics company based in Cambridge, which entered the Baltimore market in July, chose Baltimore for its launch because the city has the highest scooter ridership of all the cities it serves nationwide. The company hopes the scooters, which have adjustable seats, will be an option for people who are unable to ride a standing scooter safely. The 150 seated scooters available around the city can be found through the LINK app. Riders in lower-income communities may qualify for a 70% discount. Amy Davis/BALTIMORE SUN

addressed while also protecting public safety and data privacy.

The pandemic changed many things. When COVID-19 first struck in March 2020, ridership initially dropped by more than half but is now slowly recovering. While the total number of trips decreased across most of the city, the geographical distribution and timing of trips has looked different after the arrival of COVID-19. Notable trends include substantial declines in the proportion of trips in the Inner Harbor and at colleges/universities, and a substantial increase in the proportion of trips at hospitals, grocery stores, transit stations and Patterson Park. The once "M" shaped use pattern (reflecting the traditional travel peaks associated with commuting to and from work) is now more "bell" shaped, indicating a steep decline in work/school commuting and non-essential rides, along with an increased need for trips to essential services. Baltimore City lifted the distribution requirements for service providers in the early months of the pandemic in response to these observed shifts in travel patterns. This gave permit holders more flexibility in distributing vehicles across the city's planning districts to meet the rapidly changing patterns of demand.

These changes are reflected in other datasets as well. Google's Community Mobility Report shows a 49 percent decrease in people present at workplaces and an 18 percent increase in people staying in residential areas of Baltimore City, presumably since many residents did not commute to work and only took mostly essential trips. Interestingly, people didn't venture far from their homes as the changes in ride origins (where they begin their trip) were generally higher in magnitude than the changes in vehicle distribution (where they left the vehicle). This pattern shows a noticeable shifting away from downtown destinations toward the residential parts of the city.

Research

The USDOT Bureau of Transportation Statistics (BTS) has resources available to explore trends in micromobility in the U.S. since 2015 and uses an interactive map to track features such as docked bikeshare, dockless bikeshare and e-scooter systems.

The National Association of City Transportation Officials (NACTO) released their 2019 Shared Micromobility Snapshot, a compilation of statistics on the growth and use of shared micromobility (bike share, e-bike share and scooter share) in the U.S. The report helps create a robust picture of this nascent, vibrant and rapidly changing mobility option and industry, providing

cities, advocates and companies alike with a comprehensive look at trends, challenges and opportunities.

In 2019, the Baltimore Regional Transportation Board (BRTB) did some research to assist jurisdictions considering micromobility in achieving local goals. That work focused on how and if new and shared mobility services can be addressed in the development review processes to ameliorate or avoid negative impacts on the transportation systems in the region. A separate Best Practices memo was also prepared. The memo compiled exemplary New Mobility/shared Mobility related policies from around the country and summarized the consensus State of the Practice research. Some of that research can be found here.

Ongoing research by others considers important issues when permitting micromobility. In November of 2018, Remix (by Via) published several briefings on emerging best practices in the micromobility field (see library here). Of note for the Baltimore region is their research reviewing 17 cities' scooter and bikeshare policies, which uncovered key 'practice' areas of enforcement, fees, caps and data sharing, and included policies and practices to create the opportunity to serve the "underserved edges." These underserved edges are areas that have not typically been well-served by private (or public) shared services.

New Challenges

A recent law change required the MDOT Motor Vehicle Administration (MVA) to establish a pilot process for Personal Delivery Devices (PDD). A successful pilot was conducted on the Morgan State University campus. The pilot period ended July 1, 2022, and PDDs are now authorized to operate in Maryland. PDDs are considered an emerging and innovative micromobility technology promising to improve the efficiency of deliveries of goods to businesses and residential customers. A PDD is a powered device that:

- is operated primarily on roadway shoulders, sidewalks and crosswalks,
- is intended for the transport of property on public rights-of-way,
- weighs not more than 550 pounds, excluding cargo and
- is capable of navigating with or without the active control or monitoring of an individual.

PDDs could be the first permitted automated vehicle on the streets in Maryland. This will require reviews of the route and safety considerations from multi-disciplinary experts including staff from state and local agencies providing public safety and managing public infrastructure as well as providing notice to the general public.

The Future of Micromobility in the Region

Some services are (or very soon will be) available in many places in the region (e.g. Annapolis, Columbia Gateway, Ellicott City) and new services are expected to continue to grow. Public Safety is a major concern. While the majority of e-scooter trips end without incident, much work remains to improve comfort and safety for e-scooter riders with different levels of experience, training, and travel needs. Future service should address issues such as speed management, user education, improved roadway design, community engagement to help mitigate risks for vulnerable road users and the need for a connected network of facilities dedicated to serving micromobility.

image courtesy Fed Ex

According to the McKinsey Center for Future Mobility, the COVID-19 crisis is causing

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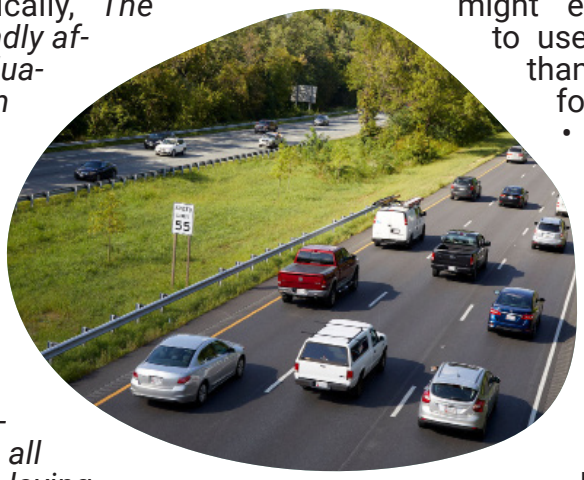
serious disruptions to the multi-billion dollar micromobility industry, and service providers are struggling. Specifically, "*The global lockdown is profoundly affecting service provider valuations, workers employed in the sector, and the speed of industry consolidation. For example, the valuation of one company operating a worldwide network of e-bikes and e-scooters recently dropped by a reported 79 percent. Another provider halted operations in six US cities and all of its European markets, laying off 30 percent of its workforce. A third company cut working hours for 60 percent of its staff while supplying a streamlined fleet of its e-scooters to healthcare workers in Germany. The lockdown has also accelerated industry-consolidation moves.*" However, McKinsey expects that in the long term, or "*next normal,*" micromobility will "*…emerge intact and thrive [with] estimates for 2030 predicting a boost of 5 to 10 percent in the number of passenger-kilometers traveled.*"



Several trends are expected to support long-term recovery and growth, such as:

- More willingness (and familiarity) by the public to regularly use micromobility,
- Average trip distances on service may increase, as observed during the COVID-19 crisis, leading to a higher revenue per trip,
- Increased awareness about personal hygiene and physical distancing might encourage consumers to use micromobility, rather than public transportation, for short trips,
- Measures to deincentivize and regulate private-car ownership and use may increase, such as instituting higher parking fees, taxes, and tolls,
- Continuous improvements in biking infrastructure and repurposing streets and lanes may incentivize micromobility use and
- The industry could lower up-front costs for consumers by establishing purchasing premiums that could make it cheaper to use shared bicycles, e-scooters, and mopeds services and/or enact mileage allowances for those using micromobility for commuting to incentivize and promote their use.

What's next?

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Overview of Vehicle Technologies

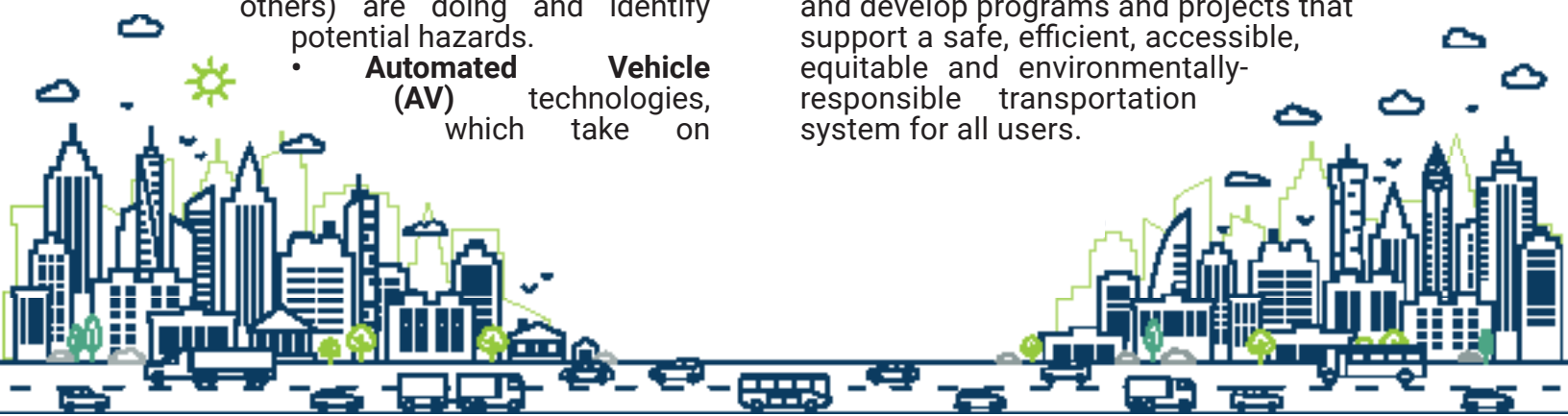
In the Baltimore region, the majority of the traveling public goes to work, school, play and other activities by automobile. Travel patterns are only expected to change slightly from pre-pandemic levels. However, while vehicles are expected to continue to remain the dominant means of getting around, the vehicle fleet is changing in ways that can address some safety issues and environmental impacts. We are seeing an ongoing rise in the number of electric and other alternatively-fueled vehicles being registered for use on our roadways.

This paper provides an overview of recent and expected advances in vehicle technologies:

- **Electric Vehicles**, including automobiles, transit vehicles, and trucks.
- **Advanced Driver Assistance Systems (ADAS),** which use a combination of sensor technologies to perceive the world around the vehicle and either provide information to the driver or take actions similar to a driver, such as sensing weather conditions or detecting objects on the road, to make real-time decisions improving safety. ADAS features can include automatic emergency braking, driver monitoring, forward collision warning and adaptive cruise control.
- **Connected Vehicles (CVs),** which use technology to either communicate with other vehicles, connect with traffic signals, signs and other road items or obtain data from a cloud. Connected Vehicles use technology to "sense" what other travelers (vehicles, bicyclists, pedestrians, wheelchairs, motorcycles, buses, trucks and others) are doing and identify potential hazards.
- **Automated Vehicle (AV)** technologies, which take on at least some aspect of a safety-critical control function (e.g. steering, throttling or braking) without direct driver input. AVs use sensors and other technologies to understand the environment and assist drivers, eventually performing driving tasks in place of a human driver. AVs can operate some or all driving functions independently from other vehicles and infrastructure using onboard sensors. Vehicles that are fully "self-driving" anywhere are a future technology not available today.
- **Connected and Automated Vehicles** combine CV and AV technologies. They use wireless communications technology to communicate with each other and with vehicles around them, with traffic infrastructure and with other travelers as well as automating some or all of the driving functions.

While these technologies have benefits on their own, they provide even greater advances for mobility, safety and the economy when combined. These technologies can support automobiles, transit vehicles and trucks, as well as enhance the safety of pedestrians, bicyclists and other human-powered travelers.

As the Baltimore Regional Transportation Board (BRTB) considers emerging technologies, it must remain flexible as we are still in the early stages of implementing these and other emerging technologies. The BRTB must be prepared to face rapid advances and implementation issues while staying true to its mission and goals and continuing to make investment decisions and develop programs and projects that support a safe, efficient, accessible, equitable and environmentally-responsible transportation system for all users.



Emerging Technologies: Electric Vehicles, Advanced Driver Assistance Systems & Connected and Automated Vehicles (CAV)

In the Baltimore region, the majority of the traveling public goes to work, school, play and other activities by automobile. The State of Maryland and local governments in the region have made significant investments in our roadway infrastructure. The Maryland Department of Transportation State Highway Administration's (MDOT SHA) system has a total replacement value of more than $39 billion. Highway facilities owned by MDOT SHA and the Maryland Transportation Authority (MDTA) are the larger facilities in the region. While these facilities carry the majority of the traveling public, they only account for roughly 16.5 percent of the road miles in the Baltimore region. Locally-owned roads account for almost 74 percent of the road miles across the region and provide direct access to individual properties. In 2019, just prior to the start of the global pandemic, 76.7 percent of the Baltimore region's residents were opting to drive alone to work according to the Census Bureau's American Community Survey.

Travel patterns are only expected to change slightly from pre-pandemic levels. However, while vehicles are expected to continue to remain the dominant means of getting around, the vehicle fleet is changing in ways that can address some of their issues of safety and impacts to the environment. In our region, we are seeing an ongoing rise in the number of electric and other alternatively fueled vehicles being registered for use on our roadways.

A More Electric and Connected Future

On August 10th of 2021, President Biden signed an executive order that called on the federal government to do all it can to support electric vehicles by setting a goal that "…50 percent of all new passenger cars and light trucks sold in 2030 be zero-emission vehicles." Electrification of our vehicles would provide multiple benefits, from reducing the carbon footprint of the transportation sector to saving money and supporting the economy.

California recently approved their Advanced Clean Cars II rule, putting them on a path to significantly change their fleet of cars to a zero-emission car, pickup truck and SUV market and deliver cleaner air and massive reductions in climate-warming pollution. This rule requires that 100 percent of new cars and light trucks sold in California be zero-emission vehicles by 2035, including plug-in hybrid electric vehicles. This action is expected to motivate manufacturers and the market in ways that may have implications

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here in Maryland. While electric vehicles are expensive to many, they cost considerably less to drive than those using diesel fuel or gasoline.

Electrifying heavy trucks and buses could provide significant benefits as these are among the most polluting vehicles on the road. Heavy-duty trucks are responsible for nearly a quarter of the greenhouse gas emissions from the nation's transportation sector, itself the biggest contributor of those emissions in the economy. Logistics companies are realizing that shifting away from internal combustion engines could provide large economic benefits to high-use commercial fleets, especially as purchase prices drop and the market changes as a result of policies like California's. Truck manufacturers also understand these economic benefits, and are already investing in zero-emission technologies. These efforts have the potential to transform at least 30 percent of their new trucks to zero-emission vehicles by 2030 — and as much as 100 percent of the additions to urban fleets of transit buses, trash trucks, postal vehicles, cargo vans and heavy-duty trucks.

Ford Motor Company's F-series dominates the medium-duty truck market and they have set a target to have 40 percent of new vehicle sales be all electric by 2030. U.S.-based bus companies are also moving forward on electrification. The bus manufacturer Proterra is experimenting with lightweight designs to increase electric vehicle range. These manufacturers understand that the private sector demand is high for zero-emission vehicles. By 2030, Amazon is aiming to have 50 percent of its shipments made by electric or non-motorized vehicles. FedEx plans to electrify its entire pickup and delivery fleet by 2040, the same year Walmart intends to complete converting its fleet to vehicles powered by electricity, hydrogen or renewable diesel fuel.

USDOT Secretary Pete Buttigieg spoke about emerging transportation technologies at CES 2022, saying, "In our lifetimes, we could see truly smart cities built on the connected technology where cars, buses and infrastructure all communicate with each other to plot safer routes and use less energy." He went on to say that "...the current decade is especially full of challenges and opportunities from developments in transportation technology," and pointed to autonomous vehicles which, while offering potential benefits, also raise "complicated, even philosophical questions about safety, equity and our workforce." In order to gain more knowledge about the safety of self-driving vehicles, Buttigeg said that the National Highway Traffic Safety Administration issued an order last year requiring manufacturers and operators of vehicles equipped with certain advanced driver-assist technologies to report crashes involving these vehicles.

With all the discussion about technologies, some very simple but innovative responses to the pandemic have been somewhat low-tech. Local governments have encouraged more walking and biking, in addition to the new ways that cities have used outdoor space for dining. Electric bicycles and other micromobility options are becoming more available to the general public in the region as well.

Advances in Vehicle Technologies

With these changes, we are also seeing advanced vehicle technologies, such as driver assistance technologies, in use. Automatic Emergency Braking, Lane Keeping Assistance, Blind Spot Warning and other advanced safety technologies help vehicles understand surroundings and either warn the driver or act to avoid a crash. These "Advanced Driver Assistance Systems," or ADAS, are passive and active safety systems designed to remove the human error component when operating vehicles of many types. ADAS systems use advanced technologies to assist the driver during driving, thereby improving driver performance. ADAS uses a combination of sensor technologies to perceive the world

around the vehicle, and then either provides information to the driver or takes action when necessary. ADAS technologies enable cars to take actions similar to a driver – sensing weather conditions, detecting objects on the road – and make decisions in real time to improve safety. ADAS features can include automatic emergency braking, driver monitoring, forward collision warning and adaptive cruise control.

not be alert to the need to take over driving quickly. This is reflected in the unfortunate and growing record of crashes, demonstrating that drivers don't yet have a firm understanding of the limitations of current driver assist technologies. There is a critical need for driver education of the capabilities and limitations of these technologies.

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Driver assistance technologies are already helping to save lives and prevent injuries. Many vehicles on the road today have the crash avoidance features discussed above. In addition, Maryland now has more than 40 connected vehicle roadside units in Montgomery and Prince George's counties that broadcast key roadway information to drivers. A lot of data is exchanged with these in-vehicle technologies and data security is a concern. In response, MDOT launched a statewide system allowing any agency to register their roadside units. This is intended to increase trust and cybersecurity of connected vehicle data exchanges.

That said, drivers need to understand the limitations of these technologies. While an ADAS can often steer, brake and accelerate vehicles on its own, the driver must be prepared to take control quickly when the technology malfunctions or cannot handle a particular situation. This remains a concern for many. Drivers may think their vehicles are self-driving, resulting in inattentive drivers that may

Connected Vehicles (CV)

Automakers are beginning to promote more connected vehicle technologies to make cars and trucks smarter and more efficient. They are leveraging technologies and solutions to improve traffic flow, an important consideration as travel patterns and congestion return to pre-pandemic levels. Connecting to databases and platforms and allowing vehicles to communicate in real time helps vehicles adjust speed, routes and avoid conflicts.

Connected Vehicle (CV) technologies use onboard communication devices and systems to address safety, efficiency and mobility on our roadways. Connected vehicles use technology to either communicate with each other, connect with traffic signals, signs and other road items, or obtain data from a cloud. The connected vehicle concept uses technology to "sense" what other travelers (vehicles, bicyclists, pedestrians, wheelchairs, motorcycles, buses, trucks and others) are doing and identify potential hazards.

Multiple types of connections are possible. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) devices typically communicate via radio signal that allow two similarly equipped vehicles to locate one another and exchange critical information in real-time. "V2X communications" (or vehicle to everything) enable vehicle and infrastructure based devices to constantly monitor location, speed and other data within a short range, providing time to warn travelers to act before a crash occurs. CV (and CAV – see below) technologies are not only transforming vehicles, they are subtly forcing a reimagining of the design of transportation infrastructure. Fully realizing the benefits of CV requires designing connectivity into roads, sensors and cameras, signage, and traffic lights.

With each CV acting as a sensor, contributing to and benefitting from the real time exchange of information with other vehicles and roadside infrastructure, huge amounts of data are created. This data is valuable, creating legal uncertainties while it becomes a product that is being sought and fought over. More advanced sensors create bigger costs and more complex questions surrounding the management and ownership of data. These issues can act as barriers to implementation of CA/CAV. These legal issues will affect every individual and organization that creates and uses CV data.

Automated Vehicles (AV)

Vehicle technology is evolving to deliver greater safety benefits than earlier technologies. Automated driving systems, or automated vehicles, are getting closer to managing the whole task of driving. Automated vehicles are those in which at least some aspect of a safety-critical control function (e.g. steering, throttle or braking) occurs without direct driver input. Automated vehicles may be autonomous (i.e. use only vehicle sensors) or may be connected (see discussion in above section) and communicate with other vehicles (i.e. V2V, V2I or V2X), or may be both connected and autonomous (see next section). Connectivity is an important input to realizing the full potential and implementation of automated vehicles. Automated Vehicles (AV) use sensors and other technologies to understand the environment to assist drivers, and eventually perform driving tasks in place of a human driver. AV can operate independently from other vehicles and infrastructure using onboard sensors. There are several "levels" of automation:

- Level 0: No Automation
- Level 1: Driver Assistance
- Level 2: Partial Automation
- Level 2+: Advanced Partial Automation
- Level 3: Conditional Automation
- Level 4: High Automation
- Level 5: Full Automation

Vehicles with an automated driving system (i.e. level 5), which some refer to as "self-driving" cars, are a future technology and are not available for purchase and use today.

Connected and Automated Vehicles (CAV)

Connected and Automated Vehicles (CAVs) combine the two technologies discussed above. They use special short-range radios to wirelessly communicate with each other and with vehicles around them, traffic infrastructure and other travelers and/or automate some or all of the driving functions. The vehicle and roadside infrastructure – like traffic signals, crosswalk signs and blind roadway curves – communicate to make traveling safer. Based on input from on-board sensors, systems on the vehicle may take over some or all of the driving functions.

CAV technology has the potential to save lives, prevent injuries and reduce crashes. Improvements to this technology are advancing and have many potential other advantages. CAV allows vehicles to see more and react faster than human drivers. Taking the human error factor out of the equation has the potential to protect drivers and passengers. CAV could also increase mobility to meet the needs of those with disabilities, the elderly or those otherwise unable to drive.

CAV technology may also help traffic move more efficiently by providing accurate data to drivers and traffic managers. As traffic moves more efficiently, there will be a reduction in vehicle emissions and improved air quality.

While the expectation is that CAVs will lead to all of these benefits, there will likely be challenges as well. Some can be identified in advance, such as the need to ensure these technologies are deployed equitably, the potential for cyberattacks on CAVs and changes to land use to accommodate CAVS. Of course, unanticipated challenges will also arise. The public sector must work with the private sector to identify and address any challenges as early as possible to maintain and even increase safety, mobility and equity.

Transit

Transit Signal Priority

To fully realize the promise of connected vehicles, transit agencies are now revisiting transit signal priority (TSP) systems in the hopes of restoring route reliability and on-time performance. TSP is a general term for operational improvements that use technology to reduce time at traffic signals for transit vehicles by holding green lights longer or shortening red lights. TSP may be implemented at individual intersections or across corridors or entire street systems. Over the last few decades, TSP systems haven't evolved much and rely on transmitters on buses that sends messages to receivers installed on traffic signals. These systems are quite expensive and require annual maintenance to guarantee operation.

Furthermore, it's hard to determine whether the system is working because the equipment generally doesn't produce event logs. When making such a large capital investment, it is very important to know whether the system is working so further expansion can be appropriately determined.

However, these systems are proving to be extremely effective due to recent technological improvements. According to a recent survey, the majority of city officials from communities leveraging transit prioritization technologies said they're seeing growing improvements in on-time performance of their transit network.

Communications access has vastly improved. With this improvement comes the opportunity to reduce the cost of TSP solutions while maximizing the current investments. To better manage their fleet, transit agencies have begun placing tracking devices on each of their vehicles. With vehicle locations known in near real-time, technology is beginning to bridge the gap between transit vehicles and traffic signals to facilitate transit priority in a more reliable, sustainable and intelligent way. This can remove the need for vehicle detection hardware at the intersection because the trackers already provide vehicle location information. Traffic engineers can now prioritize transit vehicles from greater distances and coordinate prioritization among a group of signals. Furthermore, the system provides real-time insights on which buses are currently receiving priority along with daily reports of performance metrics.

AV Shuttles

Self-driving shuttles are in use around the world. Autonomous shuttles are vehicles that move autonomously at low speeds (less than 50 miles per hour) on pre-charted routes under remote surveillance and environment restrictions for operations. Autonomous vehicles under this category are electric, are used to ferry people or deliver goods and may be manned or unmanned. Often, these are small transit vehicles that can transport 10 to 15 passengers in a relatively small area defined by pre-charted maps and well-defined routes. They also require geography-specific customizations like identifying common objects and understanding the local traffic laws and regulations. The driving scenario for the vehicle is generally simple, with well-defined emergency protocols. Shuttles typically have a remote operator functioning as a safety fallback. In addition, shuttles generally do not share the road space with faster moving traffic.

Autonomous shuttles have functioned best in closed environments such as campuses (business, industrial or educational), certain city centers and suburban neighborhoods. A self-driving shuttle had operated within National Harbor in Prince George's County, but the shuttle is no longer operating. A public-private collaboration, the Mid-Atlantic Gigabit Innovation Collaboratory (MAGIC), is now working to enable a self-driving shuttle in Westminster. This work is in the early stages and an estimate for deployment is not yet available.

Freight

Technologies that support the movement of freight and goods have already started in the region. Truck platooning is a technology involving truck operators with V2V communications technology on board. This technology enables truck operators to safely close distances

between moving vehicles, allowing two or more vehicles to be electronically synced to one another. The platooning vehicles wirelessly communicate information on braking, speed and oncoming obstacles, allowing the following trucks to have consistent and predictable driving behavior. The use of these systems drastically reduces the reaction time of the following trucks in a platoon, thereby reducing the likelihood of rear-end or chain-reaction crashes. This technology is expected to improve safety, the environment, commerce and infrastructure for Maryland's roadways and freight services.

Enabling truck platooning in Maryland required changes to state law and the creation of regulations to lift the statutory prohibition on "following too closely" for electronically connected trucks. Removing this legal barrier permitted the commercial deployment of driver-assisted truck platoons on Maryland roadways. Currently truck platoons are limited to two trucks, and each truck is required to have a driver who has a valid commercial drivers license with appropriate endorsements, has been trained on that specific vehicle's platooning system and is responsible for care and control of the vehicle they are in. While platooning trucks may follow a little closer than usual, they must still follow all traffic laws and rules of the road, and travel in a reasonable and prudent manner. Trucks approved for platooning will have a sticker displayed on the power unit near other federal and/or state regulated decals and stickers.

Platooning in Maryland is only allowed on the State's controlled access highways. The Maryland Department of Transportation, Motor Vehicle Administration (MDOT MVA) will coordinate dialogue with the platoon operator and the infrastructure owner operator for appropriate operations. As the technology evolves, consideration of platoons with more than two trucks, platoons for other heavy vehicles including buses and military vehicles, as well as platoons with a human driver in the lead vehicle and an automated driver in the following vehicle may be considered.

Personal Delivery Devices (PDD) have also begun delivery services in the region. PDDs have emerged as an innovative technology promising to improve the efficiency of deliveries. A 2021 law set out specific rules for PDDs in Maryland, authorizing PDDs and defining guidelines to operate on any highway, roadway, sidewalk, shoulder, footpath, bicycle trail or crosswalk in the state. It also sets out key definitions of what a Personal Delivery Device is, where it can operate and its size.

Morgan State University has begun the use of PDDs on campus. A private company has deployed a fleet of "KiwiBots" to provide the university's food-service provider Sodexo delivery services. MSU students can use their mobile device to place orders and meet the small, semi-autonomous robots on campus in between classes or whenever is most convenient.

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Unmanned Aerial Vehicle (UAV) systems, sometimes called drones, are also being explored as a means to transport lightweight packages, medical supplies, food or other goods. Currently, companies in the U.S. and worldwide are actively vying to define their markets and begin operations. This newer mode of transportation has the potential to change last-mile delivery economics for smaller and lighter packages by replacing deliveries currently made by traditional car, van or truck delivery services. Potential benefits of UAV delivery include reductions in traffic congestion, environmental pollution, delivery times and transportation costs. There are, however, significant challenges to broader overall usage and acceptance of drone delivery systems, including:

- Licensing, insurance, and operating requirements in compliance with Federal Aviation Administration (FAA), state, or other applicable regulations;
- Operational constraints during wind, rain, or other inclement weather;
- Cybersecurity and package security concerns;
- Bird/wildlife conflicts; and
- General public acceptance.

In addition to smaller UAVs and package delivery drones, larger Advanced Air Mobility (AAM) systems are evolving in ways that could further enhance small business delivery options, emergency service deliveries and personal travel options. As UAV, drone and AAM systems and technologies continue to evolve or become implemented, so may the need for state and local agencies to stay abreast of and collaborate on their evolving needs.

Resilience 2050: Adapting to the Challenges of Tomorrow

As the Baltimore Regional Transportation Board (BRTB) considers emerging technologies in its next long-range transportation plan (LRTP) for the Baltimore region, it must remain resilient as we are still in the early stages of implementing these and other emerging technologies. The BRTB must be prepared to face rapid advances and implementation issues and stay true to its mission and goals while continuing to make investment decisions and develop programs and projects that support a safe, efficient, accessible, equitable and environmentally responsible transportation system for all users.

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