Mobility on Demand Planning and Implementation

Current Practices, Innovations, and Emerging Mobility Futures

U.S. Department of Transportation

MOD

MOBILITY ON DEMAND

NOTICE

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16. Abstract

This report provides Mobility on Demand (MOD) planning and implementation practices and tools to support communities. The report discusses different stakeholders in the MOD ecosystem and the role of partnerships in filling spatial, temporal, and other service gaps. Additionally, the report discusses how MOD can be integrated into transportation planning and modeling. The report also discusses shared mobility implementation considerations, such as rights-of-way management, multimodal integration, data sharing, equity, labor impacts, and the role of pilot evaluations. Finally, the report discusses technology developments with implications for the MOD ecosystem, such as shared automated vehicles (SAVs), urban air mobility (UAM), and last-mile delivery innovations. This report is a practical resource with: 1) current practices for planning and implementing MOD; 2) case studies and lessons learned; 3) considerations to help public agencies advance MOD in their communities; and 4) resources and recommended reading.

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EXECUTIVE SUMMARY

Mobility on Demand (MOD) envisions a seamless mobility and goods delivery ecosystem that is safe, reliable, and equitable for all users. The United States Department of Transportation (USDOT) achieves this vision by leveraging innovative technologies and facilitating public-private partnerships that allow for a user-centric, mode-neutral, technology-enabled, and partnership-driven approach that can enhance mobility options for all travelers and support seamless delivery of goods and services.

The USDOT's MOD Program is guided by the following principles:

- User-centric – promotes choice in personal mobility and utilizes universal design principles to satisfy the needs of all users.
- Mode-neutral – supports connectivity and interoperability where all modes of transportation work together to achieve the complete trip vision and efficient delivery of goods and services.
- Technology-enabled – leverages emerging and innovative use of technologies to enable and incentivize smart decision-making by all users and operators in the mobility ecosystem.
- Partnership driven – encourages partnerships, both public and private, to accelerate innovation and deployment of proven mobility strategies to benefit all.

The USDOT's MOD Program is a multimodal program initiated by the Intelligent Transportation Systems Joint Program Office (ITS JPO), Federal Transit Administration (FTA) and the Federal Highway Administration (FHWA) to study emerging mobility services; public transportation networks and operations; goods delivery services; real-time data services; and ITS that can enhance access to mobility, goods, and services for all users.

In recent years, on-demand mobility has undergone rapid change due to advancements in technology, changing consumer preferences, and a variety of socio-demographic forces. Technology, mobility, and societal trends are changing the way people travel and consume resources, disrupting both supply of mobility and delivery options and demand for all types of trips. A core component of MOD is the provision of a dynamic supply of transportation services, providing an array of mobility and delivery options. Consumers can access mobility, goods, and services on demand by dispatching or using public transportation, shared mobility, delivery services, and other innovative strategies through an integrated and connected multimodal network. The sharing economy also allows for consumers to become mobility providers and couriers in a dynamic fashion.

MOD is based on the principle that transportation is a commodity where transportation modes have economic values that are distinguishable in terms of cost, journey time, wait time, number of connections, convenience, and other attributes. MOD enables an integrated and multimodal operations management approach that can influence the supply and demand sides of a marketplace. The supply side of the marketplace consists of the providers, operators, and devices that offer transportation services for people or goods and service delivery. The demand side of the marketplace is comprised of travelers and goods, including their choices and preferences. A variety of stakeholders both influence and are impacted by MOD, including federal agencies, state agencies, regional agencies, local governments, policymakers, the private sector, and other institutions.

Public-private partnerships can play a key role in addressing several policy challenges that could maximize the potential benefits of MOD. A few common public-private partnerships include data sharing, integration with third-party apps, rights-of-way access, risk sharing, paratransit service, off-peak service, low-density service, and first- and last- mile connections to public transportation. Stakeholders can plan and prepare for MOD by incorporating shared modes into transportation planning and modeling. In addition to planning and modeling the impacts of MOD, transportation network managers and systems operators can leverage MOD for transportation systems management and operations (TSMO) to aid in managing supply and demand.

Shared mobility services, such as carsharing, microtransit, shared micromobility (bikesharing and scooter sharing), and transportation network companies (TNCs), typically result in a variety of travel behavior, environmental, land use, and social impacts, often influenced by the context in which they are implemented. While MOD can be employed in a variety of built environments, the partnerships, policies, and deployment characteristics are almost always tailored to local context. Policies integrating shared mobility into the public rights-of-way, zoning for new and existing developments, and multimodal integration can create a network effect multiplying the effectiveness of MOD.

The impacts of MOD on data privacy, equity, and labor are common concerns associated with on-demand mobility. Sharing traveler information can help enable integrated services, such as fare payment and trip planning. However, MOD service providers typically collect an array of sensitive and personally identifiable information that requires data protection. Additionally, MOD can enhance access and opportunities for underserved communities, but it may also have adverse impacts if a particular population or community bears a disproportionate share of the benefits or adverse impacts of MOD.

MOD stakeholders may be able to overcome key equity barriers through policies and programs that enhance access to unbanked and underbanked communities (households without debit or credit card access), providing alternative access mechanisms that do not require a smartphone or the Internet to access, and providing access to physical and digital services for people with disabilities. MOD is creating new employment opportunities in some sectors of the transportation industry but is also disrupting existing labor in other transportation sectors where demand for other services have declined, such as taxis and liveries. In addition to changing the number and types of jobs available, MOD is also disrupting traditional labor practices, contributing to the growth of part-time, flexible schedule, and independent contractor work.

In the coming decades, shared automated vehicles (SAVs), urban air mobility (UAM), and last-mile delivery innovations have the potential to transform communities and mobility, both positively and negatively. The impacts of emerging technologies on auto ownership, land use, parking, and travel behavior remain to be seen. However, as these technologies come online, policymakers may need proactive policy to facilitate sustainable and equitable outcomes. What is clear is that these new technologies could likely have a disruptive impact on communities. Thoughtful planning and implementation, continued research, and a keen understanding of MOD's impacts on the transportation network will be critical to balance public goals with commercial interests and to harness and maximize the social, economic, and environmental effects of these innovations.

The USDOT is eager to understand how the growth of transportation services and on-demand mobility coupled with shifts in traveler and consumer behavior can help the nation reimagine the transportation network. The USDOT's foundational research, the *MOD Operational Concept Report*, provides an overview of MOD and its evolution, a description of the MOD ecosystem, and reviews the key enablers of the mobility system, including business models and partnerships, land use and different urbanization scenarios, social equity and environmental justice, policies and standards, and enabling technologies.

Recognizing the importance of multimodal transportation, the growth of MOD, and the commoditization of transportation services, the USDOT is pleased to present *Mobility on Demand Planning and Implementation: Current Practices, Innovations, and Emerging Mobility Futures*.

This document was developed using a multi-method approach, including a review of current literature and studies; experts representing the public and private sectors, academia, and non-governmental organizations; and webinars with thought leaders. Collectively, this information was used to develop this document. The purpose of this document is to serve as a practical resource that helps inform pilots, demonstrations, integration, research, and policies for MOD. The primer aims to provide an overview of this emerging field and current understanding—as in the years to come, MOD will continue to evolve and develop. In light of this evolution, ongoing tracking and longitudinal analysis are recommended to support sound planning and policymaking in the future.

This document provides an overview of current practices and emerging innovations. Leveraging the case studies, findings, current practices, and potential policies in this document can help stakeholders:

- Engage in public-private partnerships to bridge gaps in the transportation network;
- Prepare communities by integrating MOD into current planning and modeling practices;
- Manage network supply and demand through MOD strategies such as TSMO;
- Integrate shared mobility with existing transportation services in a variety of built environment types to support multimodal trips for all users;
- Prepare for the potential impacts of MOD through a variety of public policies;
- Integrate shared mobility and delivery services through mobility hubs, integrated fare payment, and information integration;
- Prepare for, and respond to, the impacts of MOD on labor and equity through data sharing, pilots, and research; and
- Prepare communities for innovative and emerging transportation technologies such as SAVs and UAM.

Table E-1 on the following pages provides some key takeaways for this report. Detailed takeaways are provided by topic area in each section of the report.

Table E-1. Key Takeaways

Thematic Concept	Key Takeaways
MOD Key Concepts	• Consumers are increasingly assigning economic values to modes and engaging in multimodal decision-making processes based on a variety of factors including cost, travel time, wait time, number of connections, convenience, and other attributes. • Rather than making decisions between modes, mobility consumers can make decisions among modes, in essence "modal chaining" to optimize route, travel time, and cost.
Stakeholders and Partnerships	• A number of stakeholders are involved in, influenced by, or affected by MOD. Stakeholders can have a variety of similar and differing roles, such as regulating MOD at various levels of government; providing mobility and delivery services; providing or linking to public transportation; providing information and fare payment services; and managing transportation networks. • Stakeholders can engage in a variety of partnerships to provide new, and enhance existing, transportation services. Public agencies may be able to leverage public-private partnerships to address a variety of challenges, such as bridging service gaps, improving paratransit, and sharing data.
Integrating MOD into Transportation Planning, Modeling, and Operations	• State, regional, and local public agencies can integrate MOD into long-range plans, short-range improvement programs, location-based plans, and issue-based plans to prepare for current and future changes in transportation. • Incorporating MOD in transportation modeling may be difficult due to traditional data collection and modeling methods (i.e., modes are excluded from traditional travel surveys and new supply and demand management strategies may be too complex to model given existing data limitations). • Several strategies that may be employed to enhance modeling include: incorporating travel data from shared mobility providers; including shared mobility in data collection (e.g., surveys) and models; collecting data more frequently; and using off-model analysis methods. • Communities can leverage transportation systems management and operations (TSMO) approaches to manage supply and demand across the transportation network.
Shared Mobility Implementation and Community Integration	• Shared mobility may result in a variety of impacts on travel behavior, the environment, land use, and society. More research is needed to understand the impacts of shared modes in different contexts. • Shared mobility can be implemented in a variety of built environments, such as 1) City Center; 2) Suburban; 3) Edge City; 4) Exurban; and 5) Rural. • An increasing number of shared modes and operators can impact the rights-of-way in a variety of ways. Potential adverse impacts can be mitigated through strategies that manage and allocate

Thematic Concept	Key Takeaways
	rights-of-way access among service providers (e.g., curbspace management, loading zones, and parking policies). • Incentive zoning, such as increased development density and parking reduction for the inclusion of shared mobility, is one MOD implementation strategy. • Multimodal integration can improve connectivity and traveler convenience and can be achieved through the physical co-location of mobility services, integrated fare payment across modes, and information integration, such as trip planning apps and multimodal aggregators. • The growth of delivery services may result in a variety of impacts, such as competing for rights-of-way access, increasing congestion, and disrupting trip chains.
MOD Implementation Considerations	• Pilots provide opportunities for public agencies to test innovations, validate the feasibility of deployments, measure the impacts of services, and evaluate public policies that could impact MOD. • MOD may be able to enhance accessibility for underserved communities, but it may also have adverse impacts if a particular population or community bears a disproportionate share of the benefits or adverse impacts of MOD. • The STEPS Framework (Spatial, Temporal, Economic, Psychological, and Social) can be used by stakeholders to identify, prevent, and mitigate potential equity barriers to accessing MOD. • MOD is impacting transportation labor in a variety of ways, such as creating demand for new jobs while disrupting others. • Collecting, storing, sharing, and analyzing MOD data can be challenging for a variety of stakeholders. Developing data sharing and management standards can help public agencies leverage the potential opportunities data can provide while also protecting consumer privacy and proprietary information.
Innovative and Emerging Mobility Futures	• Developments in vehicle automation and changes to existing business models are evolving to include automated vehicles (AVs) and shared automated vehicles (SAVs). • Innovative and emerging last-mile delivery options, such as robots, automated delivery vehicles (ADVs), and unmanned aircraft systems (UAS) (i.e., drones) have the potential to disrupt on-demand delivery services. • A variety of technological advancements are enabling innovations in on-demand aviation, such as new aircraft designs, services, and business models. Collectively, these innovations are referred to as urban air mobility (UAM). Other common terms include on-demand aviation, advanced air mobility, and rural air mobility (for exurban and rural communities).

COMMON TERMS

The following terms are frequently used in this document.

- **Bikesharing:** Travelers access bicycles on an as-needed basis for one-way or roundtrip travel. Users may access bicycles through annual, monthly, daily, or per-trip pricing. Many bikesharing operators cover the costs of bicycle maintenance, storage, and parking.
- **Carsharing:** Travelers gain the benefits of private vehicle use without the costs and responsibilities of ownership by joining an organization that maintains a fleet of cars and light trucks deployed in lots located within neighborhoods and at public transit stations, employment centers, and colleges and universities. Typically, the carsharing operator provides gasoline, parking, and maintenance. Generally, participants pay a fee each time they use a vehicle.
- **Courier Network Services (CNS):** These services offer for-hire delivery of food, packages, and other items. Deliveries are facilitated through internet-based applications or platforms (e.g., website, smartphone app) to connect delivery drivers using a personal transportation mode. These services can be used to pair package delivery with existing passenger trips, be exclusively for for-hire delivery services, or be mixed (for-hire drivers deliver both passengers and packages). Also referred to as flexible goods delivery.
- **Microtransit:** Privately or publicly operated technology-enabled transit service that typically uses multi-passenger/pooled shuttles or vans to provide on-demand or fixed-schedule services with either dynamic or fixed routing.
- **Mobility as a Service (MaaS):** A mobility platform in which a traveler can access multiple transportation services over a single digital interface. MaaS primarily focuses on passenger mobility (and in some cases goods delivery) allowing travelers to seamlessly plan, book, and pay for a multimodal trip on a pay-as-you-go and/or subscription basis.
- **Mobility on Demand (MOD):** MOD is a concept based on the principle that transportation is a commodity where modes have distinguishable economic values. MOD enables customers to access mobility, goods, and services on demand.
- **MOD Ecosystem:** An integrated and multimodal transportation operations management approach that can interact and/or influence the supply and demand sides of MOD. The supply side is comprised of the professionals, operators, and devices that provide transportation service (e.g., public and private mobility services, goods delivery services, transportation facilities, and information services). The demand side consists of the users of transportation services (e.g., all travelers, couriers, consumers, and modal demand).
- **Personal Vehicle Sharing:** The sharing of privately-owned vehicles where companies broker transactions between vehicle owners and guests by providing the organizational resources needed to make the exchange possible (e.g., online platform, customer support, safety certification).

- **Ridesharing (also known as Carpooling and Vanpooling):** The formal or informal sharing of rides between drivers and passengers with similar origin-destination pairings. Vanpooling, specifically, consists of seven to 15 passengers who share the cost of a van and operating expenses and may share driving responsibility.
- **Rural Air Mobility:** An emerging concept envisioning safe, efficient, accessible, and quiet air transportation system for passenger mobility, cargo delivery, and emergency management within or traversing rural and exurban areas.
- **Scooter Sharing:** Users gain the benefits of a private scooter without the costs and responsibilities of ownership. Individuals can access scooters by joining an organization that maintains a fleet of scooters at various locations. The scooter service typically provides gasoline or electric charge (in the case of motorized scooters), maintenance, and may include parking as part of the service. Generally, participants pay a fee each time they use a scooter and trips can be roundtrip or one-way. Scooter sharing includes two types of services: 1) Standing electric scooter sharing using shared scooters with a standing design with a handlebar, deck, and wheels that is propelled by an electric motor; and 2) Moped-style scooter sharing using shared scooters with a seated-design, electric or gas powered, generally having a less stringent licensing requirement than motorcycles designed to travel on public roads.
- **Shared Automated Vehicles (SAVs):** Automated vehicles that are shared among multiple users and can be summoned on-demand or can operate a fixed-route service similar to public transportation.
- **Shared Micromobility:** The shared use of a bicycle, scooter, or other low-speed mode that enables users to have short-term access to a mode of transportation on an as-needed basis. Shared micromobility includes various service models and transportation modes, such as bikesharing and scooter sharing.
- **Shared Mobility:** An innovative transportation strategy enabling users to gain short-term access to transportation modes on an "as-needed" basis. The ecosystem of shared services continues to grow and includes an array of services such as: carsharing; microtransit; transportation network companies (TNCs); shared micromobility (bikesharing and scooter sharing); shared automated vehicles (SAVs); shuttles; taxis; urban air mobility; and public transportation. Shared mobility also includes last-mile delivery services, such as: app-based deliveries (commonly referred to as courier network services), robotic delivery, drones, and other last-mile delivery innovations.
- **Shuttles:** Shuttle services use shared vehicles (typically vans or buses) that connect passengers from a common origin or destination to public transit, hospitals, employment centers, etc. Shuttle services are typically operated by professional drivers and many provide complementary amenities to passengers.
- **Taxi Services:** Taxis offer prearranged and on-demand transportation services for compensation through a negotiated price, zoned price, or taximeter (traditional or global positioning system [GPS]-based). Trips can be scheduled in advance (through a phone dispatch, website), street hail (from raising a hand on the street, taxi stand, or specified loading zone), or e-hail (using a smartphone app).

- **Transportation Network Companies (also referred to as TNCs, ridesourcing, and ridehailing**): TNCs provide prearranged and on-demand transportation services for compensation in which drivers of personal vehicles connect with passengers. Digital applications are typically used for booking, electronic payment, and ratings.
- **Transportation Systems Management and Operations (TSMO):** A set of strategies that focus on operational improvements that can maintain and even restore the performance of the existing transportation system before extra capacity is needed.
- **Unmanned Aircraft (UA):** An aircraft operated without the possibility of direct human intervention from within or on the aircraft (14 CFR 107.3).
- **Urban Air Mobility (UAM):** An emerging concept envisioning safe, efficient, accessible, and quiet air transportation system for passenger mobility, cargo delivery, and emergency management within or traversing metropolitan areas.

ACRONYMS

Acronym	Term
ADA	Americans with Disabilities Act
ADV	Automated Delivery Vehicle
AGL	Above Ground Level
API	Application Programming Interface
ATTRI	Accessible Transportation Technologies Research Initiative
AV	Automated Vehicle
CFR	Code of Federal Regulations
CNS	Courier Network Services
DOT	Department of Transportation
EO	Executive Order
EV	Electric Vehicle
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GBFS	General Bikeshare Feed Specification
GHG	Greenhouse Gas
GPS	Global Positioning System
GTFS	General Transit Feed Specification
HOV	High Occupancy Vehicle
ICT	Information and Communications Technologies
IFR	Instrument Flight Rules
IPP	Integration Pilot Program
ITS	Intelligent Transportation Systems
ITS JPO	Intelligent Transportation Systems Joint Program Office
MaaS	Mobility as a Service
MDS	Mobility Data Specification
MPO	Metropolitan Planning Organization
MOD	Mobility on Demand
MTOM DSS	Multimodal Transportation Operations Management Decision Support System
NASA	National Aeronautics and Space Administration
NTD	National Transit Database
ODD	Operational Design Domain
PDD	Personal Delivery Devices
PII	Personally Identifiable Information
RFID	Radio Frequency Identification
RTPO	Rural Transportation Planning Organization
SAV	Shared Automated Vehicle
SDC	Secure Data Commons
SPR	State Planning and Research Work Program
STEPS	Spatial, Temporal, Economic, Physiological, and Social
STIP	Statewide Transportation Improvement Program
STOL	Short Take-Off and Landing

Acronym	Term
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TIP	Transportation Improvement Program
TNC	Transportation Network Company
TOD	Transit-Oriented Development
TSMO	Transportation Systems Management and Operations
UA	Unmanned Aircraft
UAM	Urban Air Mobility
UAS	Unmanned Aerial Systems
UPWP	Unified Planning Work Program
USC	United States Code
USD	United States Dollars
USDOT	United States Department of Transportation
UTM	Unmanned Traffic Management
VFR	Visual Flight Rules
VKT	Vehicle Kilometers Traveled
VMT	Vehicle Miles Traveled
VTOL	Vertical Take-Off and Landing
WCAG	Web Content Accessibility Guidelines

CHAPTER 1: Introduction

In recent years, changing consumer preferences – coupled with advancements in technology, social networking, location-based services, wireless services, and cloud technologies – are contributing to transportation innovation and the growth of Mobility on Demand (MOD). In communities around the world, a number of converging innovations are transforming how people access and consume mobility, goods, and services. These converging trends contributing to the growth of MOD include:

- **The Growth of Shared Mobility, Shared Micromobility, and Last-Mile Delivery**: Shared mobility is an innovative transportation strategy enabling users to gain short-term access to transportation modes on an "as-needed" basis. The ecosystem of shared services continues to grow and includes an array of services such as: carsharing; microtransit; transportation network companies (TNCs); shared micromobility (bikesharing and scooter sharing); shared automated vehicles (SAVs); shuttles; taxis; urban air mobility (UAM); and public transportation. Shared mobility also includes last-mile delivery services, such as: app-based deliveries (commonly referred to as courier network services), robotic delivery, drones, and other last-mile delivery innovations. The growth of these services is having a transformative effect on communities by creating new opportunities for access, mobility, and delivery;

- **Electrification:** Electric drive vehicles (EVs) and electric devices (e.g., scooters, e-bikes, etc.) that use one or more electric or traction motors for propulsion can reduce greenhouse gases (GHGs) and other emissions, mitigating many of the transportation-related impacts associated with increased urbanization in cities. Lower pollution and maintenance requirements are contributing to increased investment, improved performance (increased range and reduced charge times), and the growing popularity of EV technology;

The MOD Vision

MOD envisions a seamless mobility and goods delivery ecosystem that is safe, reliable, and equitable for all users. USDOT achieves this vision by leveraging innovative technologies and facilitating public-private partnerships that allow for a user-centric, mode-neutral, technology-enabled, and partnership-driven approach that can enhance mobility options for all travelers and support seamless delivery of goods and services.

The USDOT's MOD Program is guided by the following principles:

- User-centric – promotes choice in personal mobility and utilizes universal design principles to satisfy the needs of all users.
- Mode-neutral– supports connectivity and interoperability where all modes of transportation work together to achieve the complete trip vision and efficient delivery of goods and services.
- Technology-enabled – leverages emerging and innovative use of technologies to enable and incentivize smart decision making by all users and operators in the mobility ecosystem.
- Partnership driven – encourages partnerships, both public and private, to accelerate innovation and deployment of proven mobility strategies to benefit all.

- **Connected and Automated Vehicles:** Connected and automated vehicles that are capable of sensing the environment and moving with little or no input from a human driver have the potential to improve safety and increase vehicle occupancy (with policy levers). Automated vehicles also have the potential to create opportunities for shared services and public transportation, such as automated pick-up and drop-off and potentially more economical and convenient demand-responsive services.

- **Digital Information and Fare Payment Integration:** With a growing number of mobility innovations, there is demand for data-enabled technologies that aggregate modes, facilitate multimodal trip planning, and integrate payment. A growing number of digital information and fare payment services are increasingly offering seamless information and payment connectivity among different transportation modes. These services can help bridge information gaps, make multimodal travel and public transportation more convenient, and enhance decision making with dynamic and real-time information throughout an entire journey; and

- **The Commodification of Transportation:** Increasingly, consumers are assigning economic values to modes and engaging in multimodal decision-making processes based on a variety of factors including cost, travel time, wait time, number of connections, convenience, and other attributes. Rather than making decisions between modes, mobility consumers can make decisions among modes, in essence "modal chaining" to optimize route, travel time, and cost.

Key MOD Characteristics

MOD is characterized by five defining attributes:

1. Commodifying transportation choices into economic terms based on cost, journey time, wait time, number of connections, convenience, and other attributes;

2. Embracing the needs of all users (travelers and couriers), public and private market participants, and services across all modes—including motor vehicles, pedestrians, bicycles, public transit, for-hire vehicle services, carpooling/vanpooling, goods delivery, and other transportation services;

3. Improving the efficiency and reliability of the transportation system and increasing the accessibility and mobility of all travelers;

4. Enabling transportation system operators and their partners to monitor, predict, and adapt to changing transportation conditions across the entire mobility ecosystem (network); and

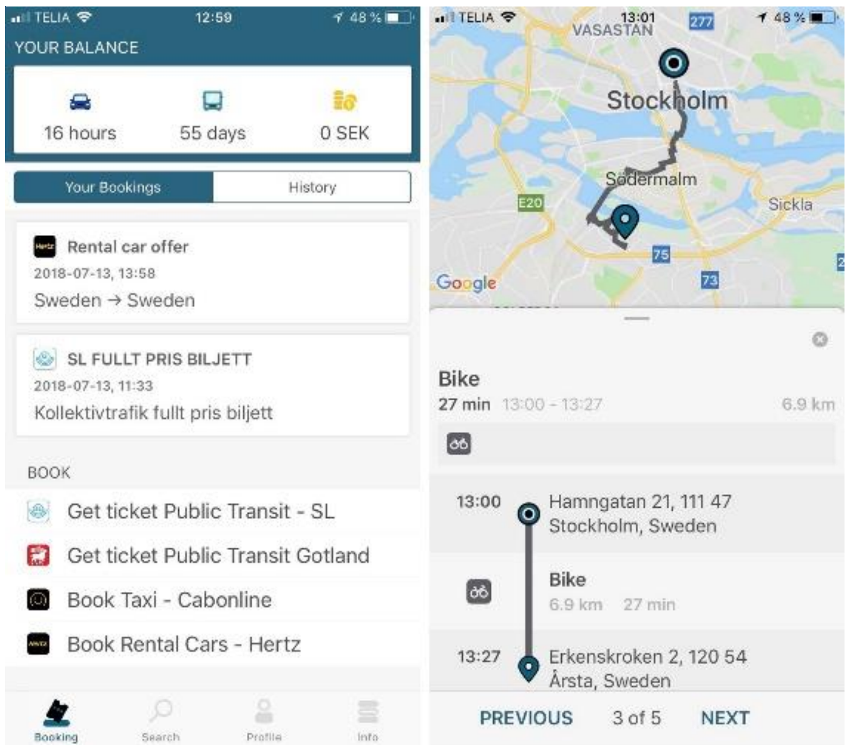
5. Maintaining the ability to receive data inputs from multiple sources and provide responsive strategies targeting an array of operational objectives.

Mobility as a Service (MaaS)

In Europe, another multimodal transportation concept known as Mobility as a Service (MaaS) is emerging. Mobility as a Service (MaaS) is a mobility marketplace in which a traveler can access multiple transportation services over a single digital interface. Although MOD and MaaS share a number of similarities, MaaS primarily emphasizes passenger mobility allowing travelers to seamlessly plan, book, and pay for a multimodal trip on a pay-as-you-go and/or subscription basis. MaaS can support MOD by providing users with a variety of transportation options (e.g., TNCs, micromobility).

For example, UbiGo in Northern Europe operates as a transportation brokerage service providing member households a mobility subscription in place of car ownership. The monthly subscription allows households to pre-purchase mobility access in a variety of increments on multiple modes, operating like a multimodal "digital punch card" for a number of transportation services (including public transportation, carsharing, rental cars, and taxis). The brokering of travel with suppliers, repackaging of services, and reselling of bundled packages are defining characteristics of UbiGo and MaaS.

Figure 1. Ubigo Interface

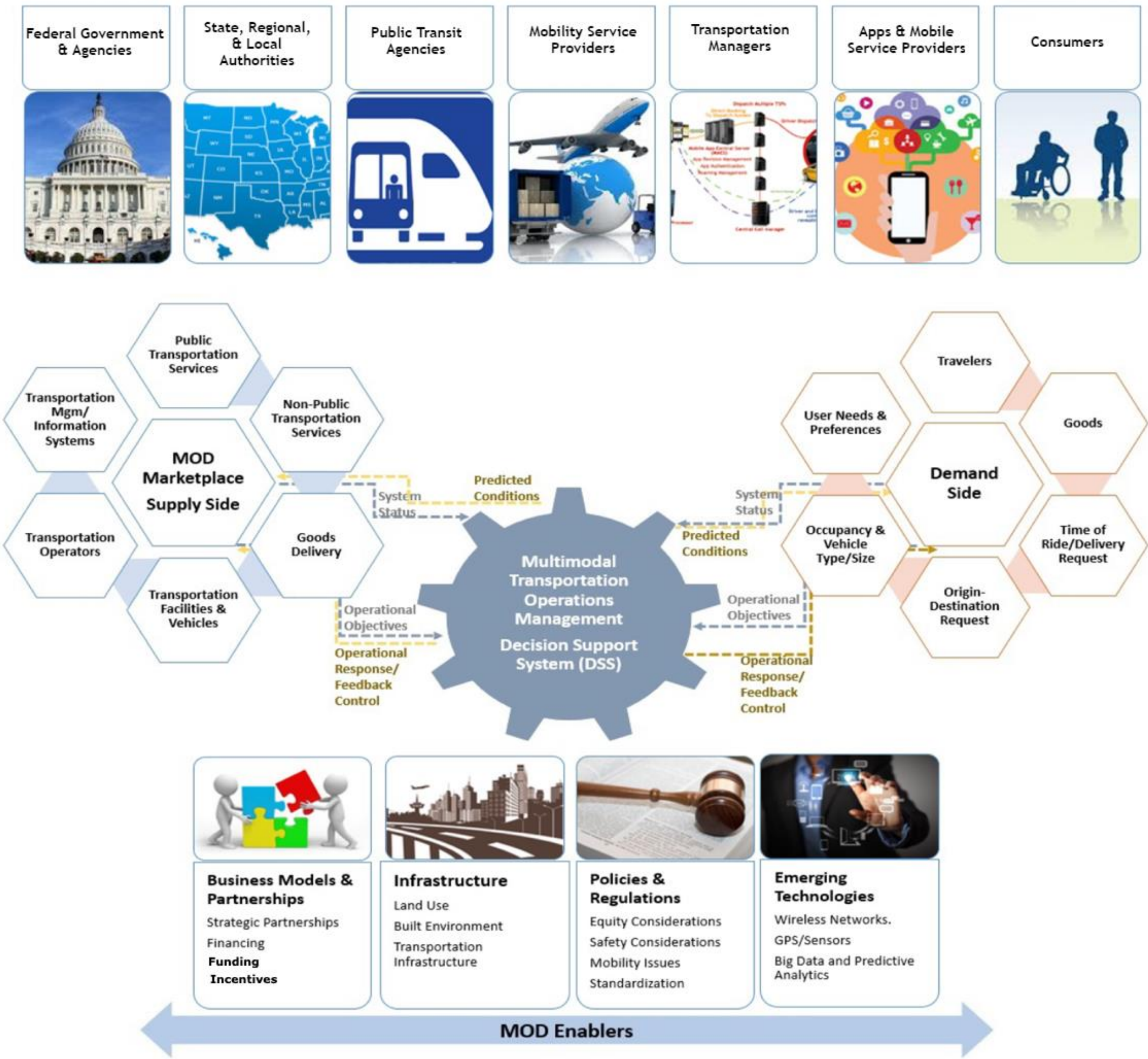


Source: Ubigo App, n.d.

The MOD Ecosystem: Marketplace, Stakeholders, and Enablers

With the support of innovations like MaaS, MOD enables an integrated and multimodal operations management approach that can influence the supply and demand sides of a marketplace. The supply side of the marketplace consists of the providers, operators, and devices that offer transportation services for people or goods and service delivery. The demand side of the marketplace is comprised of travelers and goods, including their choices and preferences (Shaheen et al., 2017). At the epicenter of the MOD ecosystem is multimodal transportation operations management, which receives data from all portions of the system, assembles those data into an overall picture of current and predicted conditions, and identifies problems considering a wide range of operational objectives applicable to the specific time period (Shaheen et al., 2017). MOD is supported by strong data governance, integrated payment processing, and shared transactional specifications. Figure 2 demonstrates MOD's vision of an integrated and multimodal transportation operations management approach that can interact and/or influence the supply and the demand sides, as well as the key enablers and stakeholders of this multimodal ecosystem.

Figure 2. Architecture for MOD and Multimodal Management



Source: Shaheen et al., 2017

The Multimodal Transportation Operations Management Decision Support System (MTOM DSS) provides an architecture for the multimodal mobility ecosystem, which includes transportation operators as a system element. Mobility providers are included within this element and have a role within the supply side of the ecosystem. Major elements of the MTOM DSS are:

- The multimodal transportation ecosystem—the transportation systems, facilities, services and associated stakeholders that serve mobility needs;
- The data and information that the mobility ecosystem feeds into the MTOM DSS; and
- The DSS that combines real-time, historic, and predicted system condition information; analyzes alternative response strategies to address current or predicted problems; analyzes the tradeoffs associated with strategies that support a number of operational objectives that vary dynamically; and produces recommended strategies for implementation by system operators.

Within the supply side of the marketplace, there are several business models:

Table 1. MOD Business Models

Business Model	Definition
Business to Consumer B2C	Providing individual consumers with access to a business-owned and operated transportation service (e.g., shared mobility).
Business to Government B2G	Providing transportation services to a public agency for public-sector related purposes.
Business to Business B2B	Providing business customers access to transportation services for work-related trips.
Peer to Peer Marketplace for Mobility Services and Goods Delivery	Maintaining a marketplace, usually an online platform between individual buyers and sellers of an on-demand service in exchange for a transaction fee. This model can take two forms: • *Mobility Services:* The platform typically provides insurance and user verification/ratings to facilitate transactions. • *Goods Delivery:* Private couriers deliver packages using their private automobiles, bicycles, scooters, or other transportation modes.
Public Transportation	Providing fixed route and/or demand-responsive services to riders.
Mobility as a Service (MaaS)/Aggregators	A service that aggregates a variety of mobility options into a single digital platform.
Transportation Data and Cloud Support Services	Supporting MOD through data and cloud services that enable transportation services.

Source: Shaheen et al., 2017

In addition to business models, four enablers that support the MOD ecosystem include:

- **Business Models and Partnerships** are evolving to meet the diverse needs of MOD consumers, service providers, and partners. Additionally, a variety of partnerships are evolving to support MOD. Common partnerships can include financing structures, risk-sharing, incentive strategies, and strategic partners. Resources including financial support, personnel services, and in-kind aid can help to support the development, testing, and implementation of MOD strategies. These resources can come from a variety of sources, such as public and private sector stakeholders. Understanding common MOD business models can help inform the role of partnerships and public policy in supporting the development, growth, and evolution of MOD (Shaheen et al., 2017).

- **Infrastructure** comprises of land use, the built environment, and transportation facilities (e.g., roads, sidewalks, bicycle paths, etc.) that can support MOD. Urban density, walkability, the availability of active transportation infrastructure, and physical design are important MOD infrastructure enablers (Shaheen et al., 2017).

- **Policies and Regulations** include enablers, such as equity, safety, mobility, sustainability, accessibility, and standardization. Policy and regulatory enablers are the best tools to address challenges with the applicability of existing laws and regulations, accessibility for people with disabilities, economic accessibility, digital poverty, and the urban and rural divide. Likewise, standardization (both technological and infrastructure) is crucial to ensure interoperability among different components of the MOD ecosystem and to enable a more efficient and usable system. The public sector has a major role as a stakeholder and an enabler affecting different transportation modes by defining legislative frameworks, ensuring fair market performance, establishing incentives, and initiating pilot programs (Cohen and Shaheen, 2016; Shaheen et al., 2016).

- **Emerging Technology** include enablers, such as satellite navigation, sensors, wireless systems, Internet of Things (IoT), mobile apps, unmanned traffic management (UTM), unmanned aerial systems (UAS), robotic delivery, big data, data analytics and management systems, machine learning, artificial intelligence, virtual reality, inclusive information and communication technology, and universal design (Shaheen et al., 2017). Technology is a key enabler of MOD and supports enhanced connectivity among travelers, goods, services, and infrastructure. Technology can also support the more efficient use of resources and emerging transportation and consumption choices.

Recognizing the growing importance of MOD, the U.S. Department of Transportation is pleased to present *Mobility on Demand Planning and Implementation: Current Practices, Innovations, and Emerging Mobility Futures*. Development of this document was made possible by the practitioners and policymakers that participated in expert interviews and stakeholder engagements in Spring and Summer 2019. It is important to note, however, that this is a rapidly evolving field, which requires ongoing tracking and evaluation. This report presents current understanding at the time of this writing.

How to Use this Document

This document was developed using a multi-method approach, including a review of current literature and studies; experts representing the public and private sectors, academia, and non-governmental organizations; and webinars with thought leaders. Collectively, this information was used to develop this document.

The purpose of this document is to serve as a practical resource that helps inform pilots, demonstrations, integration, research, and policies for MOD. Due to a variety of stakeholders that influence and are impacted by MOD, this report provides information and noteworthy practices for the public and private sectors, as well as other stakeholders interested in planning and implementing MOD. This document contains:

- Practices for planning MOD across different spatial and temporal scales;
- Practices for implementing MOD;
- Case studies and lessons learned for incorporating MOD into the planning process;
- Considerations to help public agencies advance MOD in their communities; and
- Resources and recommended reading.

The following are some suggestions for how different readers can use this document:

- **Federal Agencies:** Use the provided information to support nationwide implementation of MOD.
- **State Agencies:** Use the practices and strategies presented in this document to inform statewide transportation plans and strategies.
- **Regional Agencies:** Understand the potential benefits of MOD and ways MOD can be incorporated into regional transportation planning and modeling.
- **Local Agencies:** Learn current MOD strategies and implement them in communities.
- **Elected Officials and Policymakers:** Reference this document to aid public policy development.
- **Private Sector:** Use this document to inform best practices for operations and the development of shared mobility strategies, such as partnerships and business models.
- **Non-governmental Organizations:** Access information about current practices and emerging lessons learned for shared mobility planning and implementation.
- **Academia and Researchers:** Use this document to gain an understanding about the current state of MOD and identify potential areas of research.

Mobility on Demand Planning and Implementation Overview

Mobility on Demand Planning and Implementation provides an overview of current practices and emerging innovations. This report is organized into eight chapters:

- **Chapter 1: Introduction.** This chapter introduces the concept of MOD, including definitions, key concepts, and examples of how to use this document.
- **Chapter 2: MOD Stakeholders and Partnerships.** This chapter discusses different stakeholders in the MOD ecosystem and the role of partnerships in filling spatial, temporal, and other service gaps.
- **Chapter 3: Integrating MOD into Transportation Planning, Modeling, and Operations.** This chapter presents examples of how MOD is being integrated into transportation planning and modeling. This chapter also discusses ways that transportation system management and operations (TSMO) strategies can be used to more effectively integrate MOD.
- **Chapter 4: Shared Mobility Implementation and Community Integration.** This chapter discusses how shared mobility can be implemented in a variety of built environments and methods for implementation, such as the allocation of rights-of-way, incentive zoning, and multimodal integration.
- **Chapter 5: MOD Implementation Considerations.** This chapter describes different considerations of MOD implementation including potential impacts on data sharing and management, on the labor force, and on equity in the transportation network.
- **Chapter 6: Innovative and Emerging Mobility Futures.** This chapter summarizes technology developments that have the potential to disrupt the transportation ecosystem, such as shared automated vehicles, urban air mobility, and last-mile delivery innovations.
- **Chapter 7: Conclusion.** This chapter summarizes key findings from this report.
- **Chapter 8: Recommended Reading and Resources.** This chapter offers recommended reading and additional information on MOD topics discussed in this document.

CHAPTER 2: MOD Stakeholders and Partnerships

The supply side of the MOD ecosystem is enabled by a variety of stakeholders and partnerships. Innovative and emerging transportation services can present a wide variety of policy, financial, and communication challenges, among others. Strategic partnerships can help stakeholders confront these challenges and aid the growth and mainstreaming of MOD. Public-private partnerships can include an array of assistance ranging from financial and marketing support to providing rights-of-way and integrating shared mobility into planning processes, local ordinances, and public transit. Public-private partnerships can also provide support in the establishment of standards, data sharing, inclusion of MOD into public policy, and risk sharing. This chapter discusses MOD stakeholders, potential opportunities and challenges, and the role of public-private partnerships in supporting MOD.

MOD Stakeholders

A number of public and private sector stakeholders are involved in, influenced by, or affected by MOD. These stakeholders can have a variety of similar and differing roles, such as:

- Establishing strategies, policies, and regulations for transportation and MOD;
- Managing multimodal transportation networks;
- Providing or linking to public transportation;
- Commodifying passenger mobility and goods delivery;
- Offering on-demand access to mobility and goods delivery strategies for users;
- Increasing accessibility and goods availability through partnerships and use cases; and
- Disseminating real-time information and facilitating trip planning, payment, and data access.

Common MOD stakeholders include:

- **Federal Government:** Many branches of the government can influence MOD, including the United States Department of Transportation (USDOT), Department of Energy (DOE), Department of Labor (DOL), Department of Commerce (DOC), and Department of Defense (DOD), among others. These organizations, albeit from different angles, can play a role in establishing transportation strategies, policies, and regulations. They can also implement those strategies, make investments in pilot programs and research, and provide guidance for nationwide development of strategies:
    - **U.S. Access Board:** This federal agency promotes equality for people with disabilities through accessible design. The board helps develop accessibility guidelines and standards for the built environment, communication, information technology, medical diagnostic equipment, and transportation.

- **U.S. Department of Transportation (USDOT)**: The USDOT works to keep the traveling public safe and secure, increase mobility, and have the U.S. transportation system contribute to the nation's economic growth and development. The USDOT provides funding for investments in highways, roads, bridges, public transportation, and other transportation services and infrastructure. In addition, the USDOT maintains national standards for transportation system safety and oversees funding recipients and transportation providers for safety and compliance.
  - **Federal Highway Administration (FHWA):** The FHWA offers financial and technical assistance to state, regional, and local governments to support the design, construction, and maintenance of the National Highway System. The goal of the FHWA is to ensure that America's highways, roads, and bridges are safe and technologically sound.
  - **Federal Transit Administration (FTA):** The FTA provides financial assistance for the development of new transit systems and for improvements, maintenance, and operations of existing systems. The FTA also monitors grants and federally funded projects to ensure recipients adhere to mandated procedures.
  - **Intelligent Transportation Systems Joint Program Office (ITS JPO):** The goal of the ITS JPO is to create an intelligent transportation system through the integration of intelligent vehicles and intelligent infrastructure. The ITS JPO provides investments in major research initiatives, exploratory studies, and deployment support programs.

- **State, Regional, and Local Authorities:** These agencies implement policies and regulations by administering programs and activities, such as issuing permits, managing public rights-of-way, conducting local and regional transportation planning, and operating traffic management centers (Barbour et al., 2019). These stakeholders also serve as mobility integrators who work to combine various travel modes physically and digitally.
  - **State Departments of Transportation (DOTs):** State DOTs provide funding to plan, design, operate, and maintain roads and transportation systems. State DOTs also coordinate with other State agencies (e.g., Departments of Motor Vehicles (DMVs), State Departments of Insurance) that are responsible for the enforcement of safety standards in transportation systems (U.S. Department of Transportation, 2016).
  - **Metropolitan Planning Organizations (MPOs)**: MPOs undertake regional transportation planning activities for urbanized areas with populations over 50,000 people. MPOs are responsible for establishing regional priorities for federal transportation funding by implementing a continuous, comprehensive, and cooperative planning process among the state DOTs and local governments within the metropolitan planning organization, public transit providers, local elected officials, the public, and other stakeholder groups (Federal Transit Administration, 2019).

  - **Rural Transportation Planning Organizations (RTPOs)**: RTPOs are multijurisdictional organizations of nonmetropolitan (rural) area local officials and transportation system operators that States may assemble to assist in the statewide and nonmetropolitan transportation planning processes. RTPOs emphasize rural areas of the State. An RTPO may have additional representatives from the State, private businesses, transportation service providers, economic development practitioners, and the public (Federal Highway Administration and Federal Transit Administration, n.d.).

  - **Public Transportation Agencies:** Public transportation agencies operate and maintain public transit services to the general public in urban, suburban, and rural areas, including fixed-route transit, demand responsive transportation, and paratransit services. Some of the services include buses, trolleys, subways, light rail, commuter rail, and passenger ferries.

  - **Transportation/Traffic Managers:** These include transportation management centers that monitor network operations and, as necessary, respond to needs and allocate resources.

- **Mobility Service Providers**: These include bikesharing, car rentals, carsharing, TNCs, microtransit, scooter sharing, taxis, paratransit, and other service providers.

- **Supply Chain Managers:** These include logistics management and food, medical, and goods delivery providers who manage and run the flow of goods and materials from origin to destination, in addition to handling inventory, warehousing, packaging, security, and dispatching functions.

- **Apps and Mobile Service Providers:** These are third-party information and communications technologies (ICT) services and providers enabling on-demand service, mobile ticketing, payment, and navigation services.

- **Consumers:** These are the users of MOD who create demand for mobility, delivery, and digital services.

The benefits, opportunities, and challenges of MOD can vary by stakeholder. Table 2 provides examples of the diverse opportunities and challenges that can confront the range of MOD stakeholders. Figure 3 illustrates MOD stakeholders from public sector stakeholders on the left, service providers in the middle, and MOD consumers on the right.

Figure 3. MOD Stakeholders

Source: Shaheen et al., 2017

Table 2. Examples of Potential Opportunities and Challenges for MOD Stakeholders

Stakeholder	Potential Opportunities	Potential Challenges
Federal Government	• Establishing a framework to help manage transportation supply and demand, eliminating or reducing the need for expensive capacity-enhancing capital projects	• Maintaining a safe transportation system for all users • Improving the condition and performance of the existing transportation network • Difficulty keeping up with a dynamic, fast-changing technology or business model • Lack of clear regulatory definitions for modes and other services • Service providers initiating service without public sector consent and/or exploiting unclear legal or regulatory areas
State, Regional, and Local Authorities	• Leveraging emerging technologies to more effectively manage existing transportation supply and demand, potentially mitigating the need for expensive capacity-enhancing capital projects • Expanding service to underserved communities or user groups	• Identifying long-term resources to maintain and operate the transportation network. • Modes lacking clear regulatory definitions • Service providers initiating service without consent and/or exploiting unclear legal or regulatory areas • Difficulty keeping up with a dynamic, fast-changing technology or business model • MOD potentially having unclear or adverse impacts on travel behavior, equity, or the environment
Public Transportation Agencies	• Enhancing public transit agency preparedness for MOD by implementing proactive MOD strategies • Bridging first- and last-mile gaps through partnerships • Developing multimodal connections and mobility hubs	• Increasing competition from other transportation service providers • Private-sector service providers unwilling to share data or work toward fare and digital integration • Unclear evolution of the future role of public transportation alongside other mobility providers • Increasing need to protect data security and user privacy when collecting data

Stakeholder	Potential Opportunities	Potential Challenges
Mobility Service Providers and Supply Chain Managers	• Serving emerging markets and generating revenue through innovative services by implementing new transportation technologies and modes • Forming public-private partnerships	• Confronting an uncertain or unfriendly regulatory environment • Challenges meeting regulatory requirements, while maintaining profitability and/or protecting consumer privacy • An increasing number and variety of transportation modes may compete for limited curbspace
Transportation Managers	• Managing transportation supply and demand near real time through emerging technologies • Reducing vehicle miles traveled (VMT), lowering GHG emissions, and achieving other public-sector goals by integrating new modes	• Disruptions with other services or unintended consequences impacting other services • Adverse effects on travel behavior or the environment
Apps and Mobile Service Providers	• Providing digital services and/or integrating with or managing public sector fare payment, real-time information, and/or trip planning services • Forming public-private partnerships to facilitate multimodal trips	• Complex requirements for data sharing or fare payment resulting in limited public transit integration • Data protection and security for users
Consumers	• Consumers comparing service options and accessing mobility and goods delivery services on-demand through trip aggregators	• Services unavailable in certain neighborhoods or to certain users • Services unavailable, less reliable, or more expensive than existing service options

Key Takeaways

- A number of public and private sector stakeholders are involved in, influenced by, or affected by MOD. These stakeholders can have a variety of similar and differing roles, such as regulating MOD at various levels of government; providing mobility and delivery services; providing or linking to public transportation; providing information and fare payment services; and managing transportation networks.

- Stakeholders can confront a variety of potential opportunities and challenges regarding their role with MOD.

The Role of Public-Private Partnerships

Public agencies may partner with mobility service providers to enhance the public sector's role in transportation planning, public transportation, and rights-of-way management. Public-private partnerships can play a key role in addressing several policy challenges that could enhance the potential benefits of MOD (Shaheen et al., 2016). A few common public-private partnerships include:

- **Data Sharing:** Sharing data among mobility service providers, institutions, and public agencies can increase the understanding of MOD's impacts on travel behavior, equity, and the environment and benefit all parties. For example, Google maps has partnered with DOTs to provide information on travel speed in return for information on road closures (Sada Systems, 2018). Additionally, the California Transit Association has developed standards to improve data sharing between agencies and service providers. These standards require data to be shared in an accessible, secure, and interoperable way and can be used for managing local streets, curbspace, and travel.

- **First- and Last-Mile Connections:** Travelers may have difficulty getting to or from public transportation (commonly referred to as the first- and last-mile challenge). Public transit agencies are engaging in a variety of partnerships with mobility service providers to bridge these spatial gaps and increase access to public transportation. For example, Florida's Pinellas Suncoast Transit Authority (PSTA) subsidizes on-demand rides that begin or end at a transit station.

- **Integration with Third-Party Apps:** Public agencies can incorporate traveler information into digital platforms (e.g., websites, apps) to provide travelers with integrated trip planning and fare payment. For example, Denver's Regional Transportation District (RTD) has partnered with Uber Transit to provide information on RTD routes and RTD tickets on the Uber app.

- **Low-density Service:** Lower-density built environments may have less frequent transit service and lower transit ridership that increases the cost of providing public transportation service. Lower ridership and higher operational costs can contribute to lower levels of service for consumers (e.g., longer wait times and fewer routes). To help overcome this challenge, some public agencies are partnering with mobility service providers to offer gap filling services in lower density communities. For example, the Livermore Amador Valley Transit Authority's GoDublin! program subsidizes shared, on-demand rides within the suburban community of Dublin, California.

Denton County Transportation Authority (DCTA) MOD Partnerships – Denton County, TX

DCTA is engaging in a variety of partnerships and programs with mobility service providers in an effort to improve their local transportation service. To address service during off-peak hours (specifically 2 AM to 7AM), DCTA is partnering with Lyft to offer free rides around the University of North Texas. DCTA is also attempting to address congestion challenges in the Denton Enterprise Airport Zone through a partnership with a third-party app developer. This developer schedules a microtransit service for this area to ease traffic flow. DCTA is also looking to micromobility options to address first- and last-mile service gaps. Once bikesharing operators are approved for their permits to operate, DCTA plans to strategically implement bikesharing infrastructure to close service gaps. These partnerships allow DCTA to effectively leverage MOD to enhance the existing transportation network.

- **Off-peak Service:** Providing off-peak or late-night transportation services can be cost-prohibitive for some communities. Additionally, many travelers may not want to wait for infrequent late-night transit service after dark. Public agencies can offer alternative services or options during off-peak hours by partnering with service providers to provide demand-responsive options during periods of lower ridership. For example, Arlington County, Virginia has developed a Demand Response Transit / Microtransit service to replace fixed route transit during low ridership times.

- **Paratransit Service:** Public agencies are required to provide paratransit service in areas where fixed-route transit systems operate in case existing transportation systems are not accessible by people with disabilities. Providing equivalent level of service for people with disabilities and older adults can be expensive for public agencies and inconvenient for travelers (e.g., requiring riders to book a ride a day or more in advance). Partnering with accessible shared mobility services may be a cost-effective alternative that could provide an enhanced rider experience (e.g., reductions in minimum advanced booking timelines, shorter wait times, etc.). For example, Santa Monica, California supplements its traditional dial-a-ride paratransit system with a demand-responsive service for older adults and people with disabilities through its Big Blue Bus program.

- **Rights-of-Way Access and Management:** Shared mobility services (both operators and modes) may compete for rights-of-way, such as loading zones, curbspace, and parking. Communities, such as San Francisco and Seattle, have dedicated rights-of-way for a variety of shared modes, such as carsharing, shuttles, and shared micromobility (bikesharing and scooter sharing) (Seattle Department of Transportation, 2017). Washington, D.C. has a commercial vehicle loading zone program to manage the city's commercial loading zones. Commercial vehicle operators are required to either buy a commercial vehicle loading zone permit in advance or make a mobile payment upon parking (Federal Highway Administration, 2017a).

- **Risk Sharing:** Investing in innovative services and programs may be expensive and risky for both the public and private sectors. Public-private partnerships may be a way for stakeholders to share risk. One way this can be done is using the "subtraction model", in which the service provider values the monthly cost of providing service and subtracts monthly revenue from that collected value and bills the shortfall to the risk partner.

MOD stakeholders are engaging in a variety of public-private partnerships and certain stakeholders, like public transit agencies, have started undergoing organizational readiness changes to better accommodate these partnerships.

Los Angeles Metro Office of Extraordinary Innovations – Los Angeles, CA

The Los Angeles Metro Office of Extraordinary Innovation (OEI) was established to help identify, evaluate, develop, and implement new approaches to transportation innovation and mobility. To carry out this work, OEI has three program areas:

- **Strategic Planning – Metro Vision 2028:** This is LA Metro's plan to improve mobility in Los Angeles County and explains what the public can expect from the agency over the next 10 years. This plan includes adding more transportation options in Los Angeles, improving transportation service quality, and working collaboratively to enhance accessibility and mobility.

- **Unsolicited Proposals Program:** This program allows private sector companies working on transportation innovations to present new ideas directly to the agency for review and evaluation, jump-starting the traditional public procurement process. Proposals could lead to a demonstration, a pilot project, or in the most successful cases, full deployment across the agency's system. Partnership models could include finance-based Public-Private Partnerships (P3s) for innovative delivery of major capital investments, or new partnership models that allow the agency to leverage private sector innovation to enhance project outcomes. For example, one project that is currently being considered from an unsolicited proposal is an aerial tram connecting LA Metro's Union Station to Dodger Stadium.

- **New Mobility Program:** This program leverages pilot projects to test new service delivery methods that include greater private sector involvement, more focus on customer experience, and improved mobility and access. For example, LA Metro is currently working on developing a transit corridor in the eastern portion of the San Fernando Valley. This transit corridor will extend the current light rail system, add additional public transit stops, and adapt streets to prioritize active and public transportation.

These programs allow LA Metro to quickly explore emerging ideas and technologies and develop plans to implement new innovations. In November 2019 Metro hosted *CoMotion LA,* a global conference on urban mobility trends, to highlight emerging technologies and policies for a more connected, innovative, and sustainable future.

Key Takeaways

- MOD stakeholders can engage in a variety of partnerships to provide new, and enhance existing, transportation services.

- Federal, state, and local transportation agencies are responsible for the funding, operations, maintenance, and safety of the national transportation system and can help prepare infrastructure for MOD.

- Public agencies may be able to leverage public-private partnerships to address a variety of challenges, such as bridging service gaps, improving paratransit, and sharing data.

CHAPTER 3: Integrating MOD into Transportation Planning, Modeling, and Operations

Public agencies and stakeholders can plan for and model the potential impacts of MOD on the transportation network (McCoy et al., 2018). The U.S. Code and Code of Federal regulations (CFR) require MPOs, RTPOs, and state DOTs to continuously carry out cooperative, comprehensive transportation planning processes. These planning processes facilitate the safe and efficient management, operation, and development of multimodal transportation systems and facilities that serve mobility and freight needs (CIVITAS, 2015). Public agencies can access federal transportation funding for capital improvements, non-capital improvements, planning, and research through their respective MPO and/or state DOT transportation planning processes (Federal Transit Administration, 2019b). Working with MPOs and state DOTs can also assist public agencies in:

- Coordinating a shared vision for MOD and the associated goals, objectives, and strategies for implementation;
- Identifying customer needs and concerns through public involvement, stakeholder outreach, and demographic analysis;
- Evaluating regional impacts of transportation decisions through data collection, modeling, analysis, and scenarios;
- Maximizing agency resources (e.g., funding, staff time, data) and avoiding unnecessary duplication and redundancy;
- Managing transportation assets in a state of good repair (e.g., sidewalks, pavements, bridges, traffic signals, signage, transit vehicles and facilities); and
- Facilitating a seamless, efficient, and high-performing multimodal transportation system regarding safety, accessibility, reliability, congestion, equity, and sustainability.

In addition to planning and modeling the impacts of MOD, transportation network managers and systems operators can leverage MOD for TSMO to aid in managing supply and demand.

MOD and the Planning Process

Planning processes allow public agencies to document the current state of transportation networks and establish future goals for public policy and infrastructure investments. Transportation planning is cooperative and performance-driven and involves stakeholders, such as MPOs, state agencies, transit operators, local governments, and elected officials. Transportation planning allows these stakeholders to use input from the public, businesses, community and environmental organizations, and freight operators to develop short- and long-term priorities and goals. States, MPOs, local governments, and public transit agencies often revise their transportation plans and programs to plan for and respond to changing needs, risks, and priorities. Revisions to transportation plans and programs can allow for the integration of innovations like MOD. Incorporating MOD in transportation planning can allow public agencies to leverage the potential positive impacts of MOD, such as increased infrastructure efficiency, and mitigate potential negative impacts, such as traffic congestion and air pollution.

Planning can be done by a variety of jurisdictions covering an array of time horizons. Table 3 describes a variety of planning efforts that may be done by local governments, MPOs, and state DOTs. These planning efforts include:

- **Long-Range Plans:** These plans are used to identify transportation policies, strategies, and investments to address community needs and achieve goals, objectives, and performance targets. Long-range plans may have an individual chapter or subsection discussing MOD or incorporate considerations for MOD throughout the document.

- **Short-Range Improvement Programs**: These programs allocate transportation funding for capital and non-capital investments, planning activities, and research. Short-range improvement programs may provide funding for projects that directly support MOD implementation (e.g., bikesharing stations, mobility hubs, demand response transit services) or indirectly support MOD implementation (e.g., sidewalk construction, pavement resurfacing, travel demand modeling, household travel survey).

- **Location-Based Plans:** This type of plan evaluates existing and forecasted conditions in specific communities and corridors to address current and future transportation demand. Location-based plans may identify policies, strategies, and investments needed to support MOD.

- **Issue-Based Plans:** These plans examine transportation modes, services, technologies, and other topics to inform future policies, strategies, and investments. Issued-based plans may focus on MOD entirely or incorporate considerations for MOD in other topics (e.g., transportation safety, freight, transit).

Table 3. Local, Regional, and State Planning Processes

Planning Document	Local Governments	MPOs	State DOTs
Long-Range Plan	**Local Comprehensive Plan:** Acts as a policy guide for community development **Local Master Plan:** Determines ways to achieve local goals through land use and infrastructure planning	**Metropolitan Transportation Plan (MTP):** Identifies transportation policies and investments for the regional, multimodal transportation system and determines performance goals, measures, and targets through multi-agency performance-driven planning	**Long-range Statewide Transportation Plan:** Identifies transportation policies and/or investments for the statewide, multimodal transportation system and determines performance goals, measures, and targets through multi-agency performance-driven planning
Short-Range Improvement Program	**Local Capital Improvement Program:** Uses local, regional, or state funding for capital projects (e.g., road and bridge repair)	**Transportation Improvement Program (TIP):** Identifies transportation projects and strategies **Unified Planning Work Program (UPWP):** Reflects individual MPO's issues, strategic priorities, and planning activities	**Statewide Transportation Improvement Program (STIP):** Identifies projects across contexts and densities to improve statewide and regional transportation **State Planning and Research (SPR) Work Program:** Identifies transportation studies, research, and engagement tasks to support statewide and regional planning
Location-Based Plan	**Local Neighborhood Plan:** Allows local communities to influence the decisions that affect where they work and live **Local Thoroughfare Plan:** Identifies the location and type of roadway facilities to meet long-term growth goals	**Regional Subarea Plan:** Helps communities achieve goals of long-range plans within a smaller region **Corridor Study:** Defines relationship between a transportation corridor and adjacent land uses within a region	**Regional Subarea Plan:** Helps communities achieve goals of long-range plans within a smaller region **Corridor Study:** Defines relationship between transportation corridor and adjacent land uses throughout a state or within a region
Issue-Based Plan	**Local Modal Plan:** Addresses the needs and impacts of select modes **Local Strategic Plan:** Outlines activities and strategies to meet goals	**Regional Modal Plan:** Addresses the needs and potential impacts of select modes within a region **Regional Strategic Plan:** Guides planning and implementation strategies to support goals, programs, and initiatives	**Statewide Modal Plan:** Addresses the needs and potential impacts of select modes throughout a state or within a region **Statewide or Regional Strategic Plan:** Guides planning and implementation strategies to support goals, programs, and initiatives

Boston Region Metropolitan Planning Organization (MPO) – Boston, MA

To plan for innovative and emerging mobility technologies, the Boston Region MPO is taking steps to integrate MOD into transportation and land use planning. The MPO is engaging stakeholders at various levels of government and integrating new data tools into regional planning models. Some of the steps the Boston Region MPO is taking include:

- Including MOD in the MPO's metropolitan transportation plan,
- Using federal funds to research the impacts of shared mobility on curbspace and curbspace management practices,
- Hosting a "Ridehailing Partnerships Forum" to enhance understanding of the impacts of TNC partnerships on public transportation,
- Developing a Suburban Mobility Working Group to promote regional inclusion, and
- Issuing guidance for smaller communities to negotiate contracts and partnerships with mobility service providers.

Minneapolis 2040 Plan – Minneapolis, MN

In December 2018, the Minneapolis City Council submitted a final draft of their long-range plan, Minneapolis 2040. The Minneapolis City Council approved the draft in October 2019 and the plan will go into effect in January 2020. The plan supports the development of a shared mobility network through the following actions:

- Prioritizing innovation through pilots, evaluations, regulation, and public policy.
- Planning for carsharing and bikesharing services and their impacts on the community.
- Adjusting on-street and off-street parking guidelines in response to the growth of shared mobility.
- Supporting ridesharing in city-owned parking lots.
- Ensuring shared mobility is accessible and equitable by evaluating the demographics of innovative and emerging services.
- Requiring data sharing from TNCs to support transportation planning and public policy goals.

To support the planning process and the continued development of these planning documents, public agencies collect, manage, and analyze transportation data and stakeholder feedback. Community and stakeholder engagement can be important for incorporating MOD into planning documents. Public participation can build support for MOD and help public agencies and service providers address community needs and concerns in transportation decision-making. Proactive public engagement can also foster meaningful involvement and ensure fair treatment, so no community bears a disproportionate share of positive or negative impacts from MOD. Common engagement methods can include town halls, public hearings, open houses, focus groups, and other methods of community participation.

Citi Bike Share – New York City , NY

During the planning stages of its Citi Bike Share program, New York City's Department of Transportation (NYCDOT) conducted extensive multi-lingual public outreach including hosting 159 public meetings, 230 stakeholder meetings, and use of an interactive station planning map that yielded 65,000 comments. This process culminated in 2,881 community suggested bikesharing station locations for city consideration (New York City DOT, 2013). In 2018, Lyft bought Citi Bike with an agreement with New York City's mayor to triple the number of bikes to nearly 40,000 (Fitzsimmons and Randle, 2019). In 2019, Citi Bike expanded into the Bronx borough with additional planned expansion (Fitzsimmons and Randle, 2019).

Local governments, MPOs, and state DOTs may also engage in scenario planning to prepare for MOD business models and deployments. Scenario planning provides a framework for evaluating plausible future conditions involving emerging technologies and innovations, land uses and development patterns, financial costs and revenues, travel behaviors, and transportation system performance. Scenario planning can help communities develop shared MOD visions and plans and better manage potential risks and uncertainties.

Key Takeaways

- State, regional, and local public agencies can integrate MOD into long-range plans, short-range improvement programs, location-based plans, and issue-based plans to prepare for current and future changes in transportation.

MOD in Modeling

Transportation plans can be enhanced by incorporating MOD into models to provide a more accurate prediction of how traveler behavior may impact the transportation network. However, incorporating MOD into traditional transportation models may present challenges due to:

- **Modeling Methods:** Traditional modeling methods may employ a four-step travel demand model that includes trip generation, trip distribution, mode choice, and route selection to predict travel demand (California Senate, n.d.). Four-step models may be less informative about changes in travel behavior associated with MOD. More developed, state-of-the-art modeling methods can be developed, such as tour-based models[1] and dynamic traffic assignment[2].

- **Trip Chaining:** The definition of a chained trip is any travel between two anchors (called a tour, such as between home and work) that is direct or has an intervening stop of 30 minutes

[1] Tour-based modeling treats travel as a demand derived from the desire for activities as part of an entire trip chain, rather than travel between a single origin and destination.

[2] Dynamic traffic assignment models capture the changes in network performance by detailed time-of-day and can be used to generate time varying measures of this performance.

or less (National Household Transit Survey, 2001). Models generally account for origination and end of a trip, but not for trip chains or the travel between an origin and a destination.

- **Mode Chaining:** While tour-based travel demand models provide a more accurate representation of travel behavior by accounting for trip chaining activities that may occur between journey ends, these models typically fail to account for multiple modes that may be used to complete a given trip chain and the factors influencing decisions to use multiple modes and the modes selected. This document uses the term "mode chaining" to refer to the use of multiple travel modes in a given trip chain. The addition of mode chaining capabilities and adaptation of mode choice models to include multimodal decision-making factors would allow travel demand models to more accurately estimate the impacts of changes to the MOD ecosystem on the transportation network.

- **Data Sets:** Transportation models typically use data derived from the decennial census, demographic projections, and travel surveys that are completed every five to ten years. These data sources generally account for traditional travel modes, such as walking, cycling, private vehicle use, and fixed-route transit, but not innovative and emerging transportation services (e.g., shared mobility, MaaS, etc.). Public agencies may be able to acquire this data through partnerships with mobility service providers.

Local government and regional agency (i.e., MPOs and RTPOs) transportation planning models may lack the inclusion of MOD, which may result in less informative results. More sensitive planning models can aid in MOD planning and implementation.

San Francisco Chained Activity Modeling Process (SF-CHAMP) – San Francisco, CA

The San Francisco County Transportation Authority (SFCTA) has developed and employed SF-CHAMP to predict future travel patterns and transportation needs for the city. SF-CHAMP differs from traditional four-step travel prediction models as it is an activity-based model that considers a chain of trips, or "tour", from home to home rather than a single trip from point of origin to destination. SF-CHAMP's activity-based modeling results in predictions more sensitive to travel pattern changes and more inclusive of a wider variety of transportation options for travelers, providing a new viewpoint for transportation planning.

To incorporate MOD into transportation models, public agencies may consider:

- Using more developed, more sensitive transportation models to increase understanding of MOD's impacts (e.g., using dynamic traffic assignment to help model potential curbspace access limitations).

- Using transportation models that include MOD (i.e., shared mobility, MaaS, etc.) to predict the potential impacts and inform transportation plans and goals.

- Using innovative transportation models, such as tour-based and dynamic traffic assignment models, to better manage demand.

- Including MOD (i.e., shared mobility, MaaS, etc.) in travel surveys to understand what modes travelers are using, the trip chain, and the nature of multimodal behavior to provide agencies with more data and allow models to predict the impacts of MOD on traveler behavior and the transportation network based on changes in pricing, routes, hours of operations, and other factors.

- Collecting data more frequently, rather than the traditional data collection time periods (often five or 10 years). More frequent data collection allows public agencies to be more responsive to innovative and emerging transportation technologies.

- Using off-model analysis methods (i.e., analysis methods that do not use traditional models, such as quantitative research) to analyze data that may not be considered with traditional modeling methods. Off-model analysis could support more sensitive model forecasts.

Key Takeaways

- Incorporating MOD in transportation modeling may be difficult due to traditional data collection and modeling methods (i.e., modes are excluded from traditional travel surveys and new supply and demand management strategies may be too complex to model given existing data limitations).

- Several strategies may be employed to enhance modeling, including: incorporating travel data from shared mobility providers; including shared mobility in data collection (e.g., surveys) and models; collecting data more frequently; and using off-model analysis methods.

Transportation Systems Management and Operations (TSMO)

In addition to including MOD in the planning process and models, other strategies, such as Transportation Systems Management and Operations (TSMO), may be employed to include MOD. TSMO is a systems-based method[3] for coordinating strategies, such as MOD, to enable public agencies to optimize the performance of existing transportation systems to meet travel demand (Bauer et al., 2017; WSP, 2019; Bauer et al., 2018). TSMO can be used in a variety of ways, such as improving communication between transportation managers and incident responders in the case of roadway incidents and providing travelers with accurate and real-time information (Smith et al., 2018). TSMO strategies can also be used to leverage MOD to manage supply and demand within the transportation network to create a safer, more effective, and more comprehensive system. For example, New York City's Department of Education recently contracted with microtransit provider Via to use the company's routing software to more efficiently schedule and route the city's 10,000 school buses. Via uses algorithms to optimize transportation performance (similar to TSMO strategies).

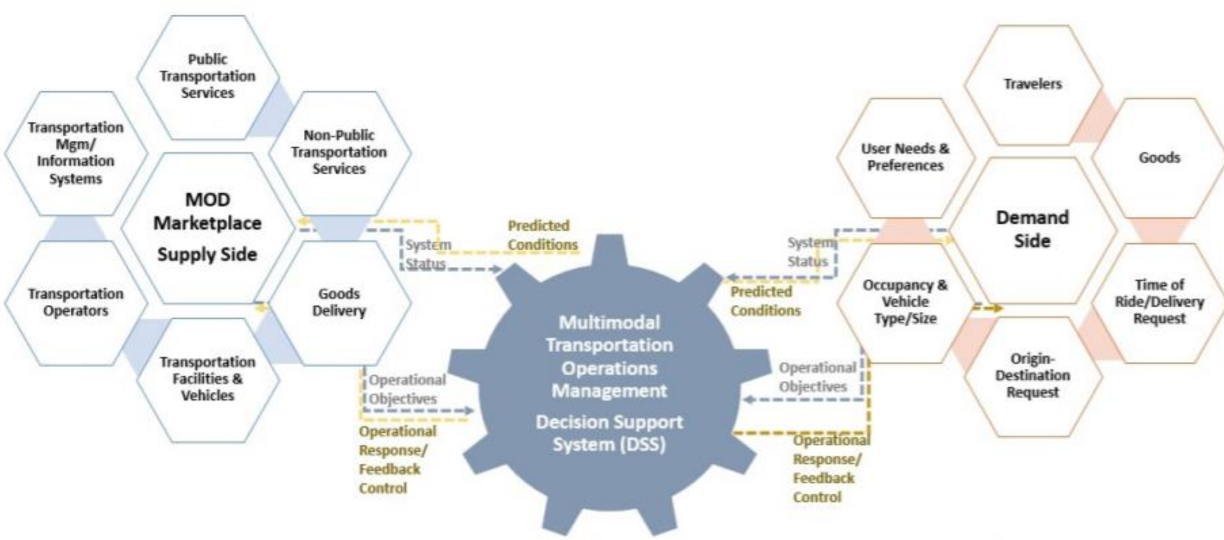
[3] A systems-based method is a problem-solving approach that requires collaborative effort between stakeholders to direct them towards an established, shared goal (CSCRS, 2019).

The Federal Highway Administration (2019a) has published information on how to leverage TSMO strategies. A few contexts in which TSMO can be leveraged in conjunction with MOD may include:

- Real time traffic management strategies to minimize delays and improve travel time reliability;
- Parking, curbside, and rights-of-way management;
- Transportation management and operations during planned events (e.g., roadway construction, parades, street festivals, sporting events, concerts);
- Transportation management and operations during unplanned events (e.g., weather events, natural disasters, traffic incidents, public transit disruptions, network outages); and
- Preferential service on lanes or facilities for particular modes (e.g., high occupancy vehicle lanes, transit signal priority).

Illustrated in Figure 4, the Multimodal Transportation Options Management and Decision Support System (MTOM DSS) is the framework through which TSMO can help manage the supply and demand sides of the MOD ecosystem. The supply and demand factors within the transportation ecosystem are defined by consumption choice and trip generation. The supply side consists of transportation services, while the demand side consists of transportation systems users (Shaheen et al., 2017).

Figure 4. Supply and Demand in the Transportation Ecosystem

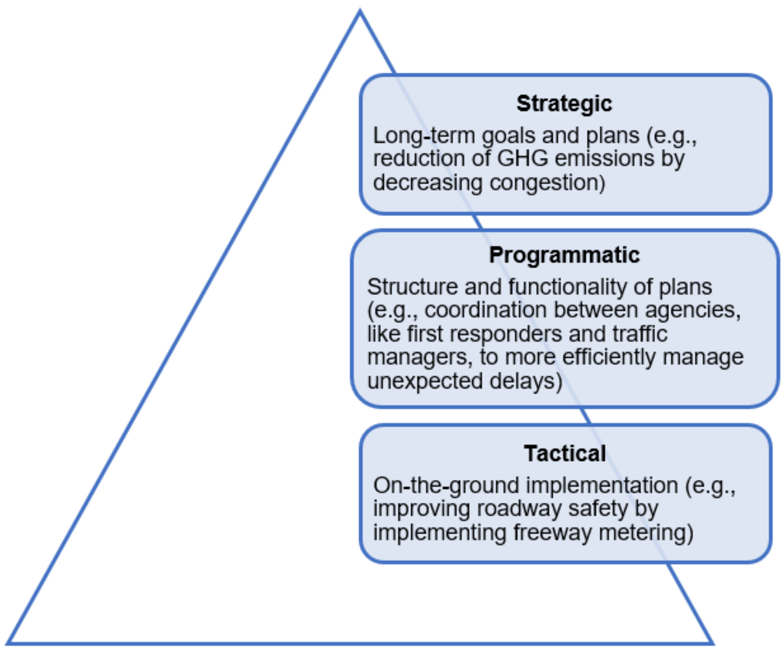


Source: Shaheen et al., 2017

Stakeholders can work through the transportation planning process to collaboratively define a common transportation-based vision for an area, develop objectives to inform and guide TSMO strategies, and identify performance measures to track progress (Federal Highway Administration, 2017b, Federal Highway Administration, 2019b; Gregory, 2018). Transportation Performance

Management (TPM) can also help stakeholders measure and understand the performance of TSMO programs (Federal Highway Administration, 2017). TSMO programs and strategies can be implemented at three levels – planning, programmatic, and tactical. Each level can help inform the subsequent level. The Dallas-Fort Worth MPO uses these levels to inform their planning decisions. Figure 5 illustrates these levels.

Figure 5. TSMO Strategies



Source: McCoy et al., 2018

The division of TSMO principles into different levels allows organizations to more efficiently manage the supply and demand sides of the MOD ecosystem. According to Smith et al. (2018) these leveled approaches to TSMO allow organizations to leverage MOD to monitor, predict, and influence conditions across a mobility ecosystem to:

- Manage travel demand in terms of location, time, and intensity of demand;
- Anticipate and respond to planned and unplanned events; and
- Provide travelers and couriers with real-time information.

Examples of tactical TSMO strategies for MOD are summarized in Table 4. More information on TSMO can be found on the FHWA TSMO website: https://ops.fhwa.dot.gov/tsmo/index.htm

Table 4. Transportation Network Goals and TSMO Strategies

	Goal	TSMO Approach
Shared and Active Transportation Use	Reduce Commuter Travel	Reducing commuter travel in private vehicles by offering financial incentives, supporting telecommuting or alternative work schedules, and offering services, such as ridesharing
	Decrease Personal Vehicle Use	Using MOD data to provide information on current and expected travel conditions, pricing, parking, delays, events, and availability to increase awareness of mobility options
	Develop Mobility Hubs	Co-locating transportation services and modes (e.g., fixed-route transit, on-demand services) to create mobility hubs and encourage the use of these services
	Increase Carsharing	Developing carsharing services and supporting these services through infrastructure, such as loading zones and park-and-ride areas
	Improve Public Transportation Efficiency	Implementing infrastructure for public transportation services (e.g., bus lanes) to improve travel time reliability and minimize the impacts of congestion
	Increase Micromobility and Active Transportation Use	Offering micromobility services and supportive infrastructure, such as trails, bike lanes, and enhanced traffic signal detection and timing for pedestrians and micromobility
Demand Management	Improve Demand Management	Dynamically managing, controlling, and influencing travel demand by offering ridesharing and on-demand modes and using predictive traveler information
	Improve Parking Management	Providing real-time information to vehicle owners and operators on parking availability and pricing based on location and time of day
	Improve Incident Management	Using vehicle location tracking services and dynamic routing to efficiently dispatch first responders and emergency personnel to incidents ranging in scale from traffic incidents to evacuations
Integrated Mobility	Integrate Corridor Management	Linking major origins and destinations by combining adjacent surface transportation (e.g., freeways, rail, bike lanes, and sidewalks)
	Improve Connectivity	Offering on-demand transportation modes through public or private providers
	Offer First- and Last-Mile Connections	Integrating services, such as bikesharing and carsharing, at transit stations and stops
Traveler Information Services	Provide Real-Time Travel Information	Using probe surveillance through field-to-vehicle devices to provide information on travel conditions, such as average speeds, delays, and incident reporting, to travelers to allow them to select their preferred mode of transportation
	Provide Route Guidance	Providing trip planning services that include multimodal routes and service information

Source: McCoy et al., 2018; North Central Texas Council of Governments, 2013; City of Seattle, 2017; Diamante, 2019; Federal Highway Administration, 2016; Federal Highway Administration, 2017c

Leveraging MOD for Emergence Response and Recovery

Natural and man-made disasters are more common than many people realize and evacuations remain a common strategy to ensure safety. Due to the heavy reliance on private vehicles in the U.S., evacuations using personally-owned automobiles have historically been the focus of many emergency managers (Wong and Shaheen, 2019). However, this can be problematic for public transit-dependent and carless households who may lack transportation access in an emergency. Research has found that one-third of the 50 largest cities in the U.S. do not have evacuation plans, and less than half of the cities with evacuation plans mention carless or vulnerable populations (Wong and Shaheen, 2019). Two strategies that may be used to increase transportation and housing capacity and redundancy during emergency evacuations and their aftermath include:

- Homesharing: the sharing of a residence, and
- Shared mobility: the shared use of a transportation mode for passenger mobility and goods delivery.

Shared mobility and homesharing present opportunities for emergency management agencies and emergency support functions to incorporate on-demand transportation and shelter resources into disaster preparedness planning and emergency response. During the California wildfires in 2017-18, Airbnb, Lyft, and Uber waived fees and offered various promotions to provide supplemental emergency transportation and housing (Wong and Shaheen, 2019). Similarly, Waze has worked with public agencies to provide information on road closures and shelter availability to tropical storm and hurricane evacuees along the Eastern Seaboard (Waze, 2019).

Waze Connected Citizen Program – Boston, MA

Waze's Connected Citizens Program provides communities with crowdsourced data to aid in infrastructure and planning decisions to improve roadway operations (Waze, 2018). In Boston, Massachusetts, the city used Waze data to improve congestion by identifying high-traffic intersections as part of Waze's Connected Citizen Program. Boston adjusted the signal timing at the identified intersections to improve traffic flow. Boston also used Waze data to create a heat map of the city to identify areas that were prone to vehicle double parking so the city could dispatch traffic officers. According to a Waze-authored analysis, the city improved congestion 18% month-over-month from these efforts (Waze, 2018).

Key Takeaways

- Communities can leverage TSMO approaches to manage supply and demand across the transportation network.

CHAPTER 4: Shared Mobility Implementation and Community Integration

Implementing MOD through shared mobility and community integration can support seamless multimodal trips. This section discusses how shared mobility can be implemented in a variety of built environments. In addition, this chapter discusses implementation methods, such as the allocation of rights-of-way, incentive zoning, and multimodal integration. The chapter also discusses pilot projects, and how they can be used to evaluate the impacts of shared mobility. Finally, the chapter discusses the role of last-mile delivery innovations in disrupting mobility and the trip chain.

Shared Mobility Implementation

A core component of the MOD ecosystem is shared mobility—the shared use of a vehicle, bicycle, or other mode that enables users to gain short-term access to transportation modes on an as-needed basis. This section provides definitions of shared modes, an overview of the current understanding of shared mobility's impacts, and policy frameworks for implementing shared mobility services.

Shared mobility includes various travel modes and service models that meet the diverse needs of users including: carsharing, microtransit, personal vehicle sharing, public transportation, ridesharing (carpooling and vanpooling), shared micromobility (bikesharing and scooter sharing), shuttles, taxis, and transportation network companies (also known as TNCs, ridesourcing, and ridehailing). Sharing can include sequential sharing (i.e., different users share the same transportation vehicle or equipment, one after the other) or concurrent sharing (i.e., sharing of the same transportation vehicle or equipment by multiple non-household users for the same trip).

Definitions of Common and Emerging Shared Modes

Table 5 provides definitions of common, innovative, and emerging shared modes.

Table 5. Definitions of Common, Innovative, and Emerging Shared Modes

Modes	Definition
Bikesharing[2]	Users access bicycles on an as-needed basis for one-way (point-to-point) or roundtrip travel. Bikesharing provides a variety of pickup and drop-off locations, enabling an on-demand and low-emission form of mobility. The majority of bikesharing operators cover the costs of bicycle maintenance, storage, and parking. Users join the bikesharing organization on an annual, monthly, daily, or per-trip basis. Bikesharing typically includes one of three common modes: • *Station-based:* Bikesharing kiosks are typically unattended and concetrated in urban settings and offer one-way service where bicycles can be picked up or returned to any station. • *Dockless*: A bicycle can be picked up and returned to any location within a predefined geographic region. • *Hybrid:* Bicycle users can check out bicycles from a station and end their trip by either returning it to a station or a non-station location. Alternatively, users can pick up dockless bicycles and end their trip by returning it to a station or non-station location.
Carsharing[1]	Individuals can gain the benefits of private vehicle use without the costs and responsibilities of ownership by joining a carsharing organization. Members typically purchase a membership and pay a fee each time they use a vehicle. Members have access to a fleet of cars and light trucks deployed in parking lots within neighborhoods, at public transit stations, employment centers, and colleges and universities. Typically, the carsharing operators provide gasoline, parking, and maintenance.
Courier Network Services[1] (CNS or flexible goods delivery)	These services offer for-hire delivery of food, packages, and other items for compensation. They use Internet-based platforms (e.g., website, smartphone app) to connect delivery people to customers using personal transportation modes. These services can be used to pair package delivery with existing passenger trips, be exclusively for for-hire delivery services, or be mixed (for-hire drivers deliver both passengers and packages).
Microtransit[1]	This mode can be privately or publicly operated and is a technology-enabled transit service that typically uses multi-passenger/pooled shuttles or vans to provide on-demand or fixed-schedule services with either dynamic or fixed routing.
Personal Vehicle Sharing[1]	Privately owned vehicles can be shared through a company which brokers transactions between car owners and renters by providing the organizational resources needed to make the exchange possible (e.g., online platform, customer support, safety certification).
Ridesharing[1] (Carpooling or Vanpooling)	This service can be formal or informal and features the sharing of rides between drivers and passengers with similar origin-destination pairings. Vanpooling, specifically, consists of seven to 15 passengers who share the cost of a van and operating expenses and may share driving responsibility.

Modes	Definition
Rural Air Mobility	An emerging concept envisioning a safe, efficient, accessible, and quiet air transportation system for passenger mobility, cargo delivery, and emergency management within or traversing rural and exurban areas.
Scooter Sharing[2]	Users gain the benefits of a private scooter without the costs and responsibilities of ownership. Individuals can access scooters by joining an organization that maintains a fleet of scooters at various locations. The scooter service typically provides gasoline or electric charge (in the case of motorized scooters), maintenance, and may include parking as part of the service. Generally, participants pay a fee each time they use a scooter and trips can be roundtrip or one-way. Scooter sharing includes two types of services: • *Standing electric scooter sharing:* Shared scooters with a standing scooter design with a handlebar, deck, and wheels that is propelled by an electric motor that can be picked up and returned to any location or to a charging station; and • *Moped-style scooter sharing:* Shared scooters with a seated-design scooter that can be rented and parked at the curb.
Shared Automated Vehicles[3] (SAVs)	This service allows automated vehicles to be shared among multiple users. SAVs can be summoned on-demand or operate a fixed-route service.
Shuttles[1]	Shuttle services use shared vehicles (typically vans or buses) that connect passengers from a common origin or destination to public transit, hospitals, employment centers, etc. Shuttles services are typically operated by professional drivers and many provide complementary amenities to passengers.
Taxi Services[1]	Taxis offer prearranged and on-demand transportation services for compensation through a negotiated price, zoned price, or taximeter (traditional or GPS-based). Trips can be scheduled in advance (through a phone dispatch, website), street hail (from raising a hand on the street, taxi stand, or specified loading zone), or e-Hail (using a smartphone app).
Transportation Network Companies[2] (ridesourcing, ridehailing, and TNCs)	TNCs provide prearranged and on-demand transportation services for compensation in which drivers of personal vehicles connect with passengers. Digital applications are typically used for booking, electronic payment, and ratings.
Urban Air Mobility[2] (UAM)	An emerging concept envisioning safe, efficient, accessible, and quiet air transportation system for passenger mobility, cargo delivery, and emergency management within or traversing metropolitan areas.

Adapted From: [1]Cohen and Shaheen, 2016; [2]Shaheen, Cohen, and Zohdy, 2016; [3]SAE International 2018

Impacts of Shared Mobility: Current Understanding

Shared mobility has resulted in a number of social, environmental, and behavioral impacts, and an increasing body of empirical evidence supports many of these relationships. The various effects can be grouped into four categories:

1. Travel behavior;
2. Environmental impacts (e.g., GHG emissions);
3. Land use; and
4. Social.

The effects of shared services can be both positive and negative, and vary by mode and deployment context, such as population density, the built environment, and public transit accessibility. More research is needed to gain a better understanding of the factors that may influence the impacts of shared mobility. This section summarizes key findings from impact studies of carsharing, microtransit, ridesharing, shared micromobility, and TNCs.

Impacts of Carsharing

A number of studies have documented the impacts of carsharing, predominantly based on self-reported survey data. These studies collectively show the following commonly associated outcomes of carsharing:

- Sold vehicles or delayed or foregone vehicle purchases;
- Increased use of some alternative modes of transportation (e.g., walking, biking);
- Reduced vehicle miles/kilometers traveled (VMT/VKT);
- Increased access and mobility for formerly carless households;
- Reduced fuel consumption and GHG emissions; and
- Greater environmental awareness.

From: Cohen and Shaheen, 2016.

Table 6 provides a summary of key findings from roundtrip, one-way, and peer-to-peer carsharing studies in North America.

Table 6. Summary of Carsharing Impacts

Operator and Location	Authors, Year	Number of Vehicles Removed from the Road Per Carsharing Vehicle	Members Selling Personal Vehicle %	Members Avoiding Vehicle Purchase %	VMT/VKT Change % Per Member	Average Monthly Cost Savings per Member	Participants Walking More %	Participants Taking Transit More %
Short-Term Auto Rental San Francisco, CA	(Walb and Loudon, 1986)		15.4	43.1				
Arlington Carsharing (Flexcar and Zipcar) Arlington, VA	(Price and Hamilton, 2005)		25.0	68.0	-40.0		54.0	54.0
	(Price et al., 2006)		29.0	71.0	-43.0		47.0	
Carsharing Portland Portland, OR	(Katzev, 1999)		26.0	53.0		154.0 USD		47.0
	(Cooper et al., n.d.)		23.0	25.0	-7.6		25.8	13.5
City Carshare San Francisco, CA	*Year 1* (Cervero, 2003)		2.5	60.0	-3.0[a]/ -58.0[b]			
	Year 2 (Cervero and Tsai, 2004)	6.8	29.1	67.5	-47.0[a]/ 73.0[b]			
	Year 3 (Cervero et al., 2007)				-67.0[a]/ 24.0[b]			
PhillyCarshare Philadelphia, PA	(Lane, 2005)	10.8[c]	24.5	29.1	-42.0	172.0 USD		

Operator and Location	Authors, Year	Number of Vehicles Removed from the Road Per Carsharing Vehicle	Members Selling Personal Vehicle %	Members Avoiding Vehicle Purchase %	VMT/VKT Change % Per Member	Average Monthly Cost Savings per Member	Participants Walking More %	Participants Taking Transit More %
TCRP Report – Surveyed Members of More Than Nine Carsharing Companies North America	(Millard-Ball et al., 2005)				-63.0		37.0	40.0
Surveyed Members of 11 Carsharing Companies US and Canada	(Martin and Shaheen, 2010)	9.0 to 13.0	33.0	25.0				
	(Martin et al., 2010)				-27.0		12.0	22.0[d]
Zipcar U.S.	(Zipcar, 2005)	20.0	32.0	39.0	-79.8	435.0 USD	37.0	40.0
Modo Vancouver, Canada	(Namazu and Dowlatabadi, 2018)	5.0		55.0				-41.0 to -55.0 [d]
Car2Go U.S. and Canada	(Martin and Shaheen, 2016)	7.0 to 11.0	2.0 to 5.0	7.0 to 10.0	-6.0 to -16.0		-2.0 to 25.0	-43.0 to 3.0
Car2Go Vancouver, Canada	(Namazu and Dowlatabadi, 2018)	6.0		55.0				-41.0 to -55.0 [d]
Car2go San Diego, CA	(Shaheen et al., 2018a)						25.0	-12.0
Getaround, RelayRides	(Shaheen et al., 2018b)		0.14	0.19			13.0	1.0 to 2.0

Operator and Location	Authors, Year	Number of Vehicles Removed from the Road Per Carsharing Vehicle	Members Selling Personal Vehicle %	Members Avoiding Vehicle Purchase %	VMT/VKT Change % Per Member	Average Monthly Cost Savings per Member	Participants Walking More %	Participants Taking Transit More %
(Turo), and eGo Carshare US								
Getaround Portland, OR	(Dill et al., 2017)			0.44				-20.0[e]

Adapted from Shaheen et al., 2016.

[a] Reflects existing members' reduction in VMT/vehicle kilometers traveled (VKT).

[b] Reflects only trial members' reduction in VMT/VKT.

[c] Reflects vehicles removed by members who gave up a car.

[d] Reflects percentage of users for which carshare was an alternative to transit.

[e] Reflects percentage of users for which a carshare trip replaced a transit trip.

Table 6 illustrates the high percentage of study participants (15% to 33%) who sold their car as a result of participation in carsharing programs. These studies generally indicate that carsharing encourages members to delay or avoid vehicle purchases. Some studies, specifically those in Portland and Philadelphia, also document potential cost savings for members participating in carsharing programs (Briggs, 2019). Many studies also show a decrease in VMT/VKT (from 3% to 79%) as well as in increases in walking and public transit ridership.

Impacts of Microtransit

While studies on the impacts of microtransit are still emerging, a study of the former microtransit service, Bridj, and the Kansas City Area Transportation Authority (KCATA) found:

- Affordability and convenience were the most common motivations for using microtransit. 56% of survey respondents said they used microtransit because it was cheaper than other options, and 39% said it was more comfortable than alternatives. Approximately 33% of respondents used microtransit because it allowed greater flexibility than alternative transportation modes.

- The majority of respondents (89%) walked to or from a RideKC: Bridj stop. It took about one third of the respondents five minutes or less to get to the RideKC: Bridj stop from their residence or workplace.

- More than half of the respondents used RideKC: Bridj only in the afternoon. This could potentially be because the service operated in the areas surrounding the University of Kansas Medical Center which had many hospital workers with shifts outside typical working hours.

- Approximately one third of respondents would have driven alone for their most recent trips had RideKC: Bridj not been available. Another third of respondents would have taken a typical KCATA bus if RideKC: Bridj was not available. Roughly 22% of respondents would have used a TNC.

- Respondents (25%) stated that they drove alone less often because of RideKC: Bridj and 16% of respondents rode the KCATA streetcar more frequently because of RideKC: Bridj.

- All of the respondents stated that they would possibly, probably, or definitely use RideKC: Bridj for a $2 fare. However, 23% of respondents said they would not use RideKC: Bridj if the fare was $3.

- Respondents (67%) said they were interested in RideKC: Bridj if the service area was expanded. This suggests that the service area may have been a factor in limiting microtransit ridership.

Further information on the partnership between KCATA and Bridj can be found in [RideKC: Bridj Pilot Evaluation: Impact, Operational, and Institutional Analysis].

Impacts of Ridesharing

A number of societal, employer, and individual benefits have been attributed to ridesharing, and an increasing body of empirical evidence supports many of these relationships—although the magnitude of ridesharing's costs and benefits for travelers is unclear. Carpools are difficult for researchers to observe and record, and as a result carpooling has often been referred to as the "invisible mode" (Minett, n.d.; Burris and Winn, 2006; GCN, 2019). The available findings, however, do shed light on the demographic characteristics and travel behavior patterns of carpoolers. Empirical and anecdotal evidence indicates that carpooling provides numerous benefits including:

- Expanded accessibility and economic opportunity for carless households or households unable to obtain drivers' licenses (Liu and Painter, 2012);
- Congestion mitigation and reduced fuel consumption (Minett and Pearce, 2011; Erhardt et al., 2019);
- Reduced parking demand and need for parking space (Shoup, 2011);
- Reduced energy consumption and emissions (Environmental Protection Agency, 2005; Bureau of Transportation Statistics; 2003);
- Reduced VMT for workplace commutes (Noland et al., 2006);
- Cost savings for public agencies and employers (Herzog et al., 2006; Boarnet et al., 2014);
- Shared travel costs (Boarnet et al., 2014);
- Travel time savings from high occupancy vehicle (HOV) lanes (City of Seattle, 2017); and
- Reduced commute stress (Dorinson et al., 2009).

Despite the uncertain magnitude of impacts, ridesharing participants have reported experiencing cost savings due to shared travel costs, travel-time savings through use of HOV lanes, and reduced commute stress potentially as the result of shared driving responsibilities. Additionally, commuters who participate in ridesharing frequently have access to preferential parking and additional incentives, such as rewards programs that provide money or gift cards for carpooling. As fleets become cleaner and more efficient, the proportion of aggregate emission reduction due to ridesharing will be lessened. It is also important to note that carpooling could lead to induced demand due to reduced travel times and costs, this should be factored into calculations of the net VMT impacts of this mode (Chan and Shaheen, 2012).

Impacts of Shared Micromobility

A number of North American studies have documented the impacts of station-based bikesharing, while the early studies of dockless bikesharing and dockless scooter sharing are emerging. Studies of shared micromobility have documented impacts in four key areas:

- **Accessibility:** Shared mobility, such as micromobility devices, may block access for pedestrians or individuals with disabilities.
- **Environment:** Several studies indicate that shared micromobility reduces GHG emissions by replacing personal vehicle trips (Shaheen et al., Forthcoming). However, additional environmental considerations include lifecycle impacts associated with support staff using vehicles to rebalance the devices, as well as manufacturing, recycling, and replacing devices and batteries (Fishman et al., 2014; Fischer et al., 2012).
- **Mode Substitution:** Mode replacement of shared micromobility systems (station-based and dockless) appear to vary by service model, device, and location of the study (LDA Consulting, 2013). Additional studies will be needed to clarify impacts on mode choice.
- **Public Health:** Shared micromobility may increase the use of active modes. A study of station-based bikesharing in Oregon found an increase in physical activity among users. An assessment of Portland's four-month pilot of standing electric scooter sharing found that scooter sharing attracted new people to active transportation (such as walking and biking) (Portland Bureau of Transportation, 2019).
- **Safety:** Studies indicate that shared micromobility users often do not wear helmets, but additional research is needed to determine if these modes are more dangerous than other transportation modes (Fishman et al., 2014; Fishman et al., 2015). Although studies have documented a high-number of scooter-related injuries and hospitalizations, more research needs to be conducted to understand risky riding behavior, safe speeds, and riding locations that most contribute to injury for scooter sharing users (Shaheen et al., Forthcoming).

Impacts of Transportation Network Companies (TNCs)

Studies on the impacts of TNCs have documented varied impacts on VMT, mode choice, vehicle ownership and use, and public transit ridership. These impacts are typically impacted by local characteristics such as urban density, the built environment, public transit accessibility, public policy, and other factors (Alemi et al. 2018; Brown and Taylor, 2018; Clewlow and Mishra, 2017; Feigon and Murphy, 2018; Hampshire et al., 2017; Henao 2017; Martin et al., 2019). TNCs may have some of the following impacts:

- Increasing access and mobility for non-vehicle owners;
- Increasing for-hire vehicle service availability, particularly in the evening and on weekends and in smaller markets where taxi service is limited or unavailable; and

- Affecting labor in various ways, including increased employment opportunities and varying upward and downward wage pressures (when accounting for hourly rates, app fees, employee versus independent contractor status, and worker benefits).

TNC impacts on vehicle trips, occupancy, VMT, GHG emissions, and other transportation modes can vary as well. TNCs may result in increased VMT and associated GHG emissions when driving to areas with higher passenger demand, deadheading (i.e., TNC vehicles driving without a passenger in the vehicle) while awaiting a ride request and/or driving to pick up a passenger, and completing the ride itself. However, TNCs can also reduce VMT and GHGs through behavioral change, such as riders who decide they no longer need to own a car due to TNC availability. TNCs can also have substitutive effects on existing transportation modes, such as changes in active and public transportation use. Table 7 summarizes findings from recent studies on the mode substitution impacts of TNCs.

Table 7. TNC Mode Substitution Impacts

Study Authors/ Location/Survey Year of Study	Rayle et al.* San Francisco 2014	Henao* Denver and Boulder, CO 2016	Gehrke et al.* Boston 2017	Clewlow and Mishra† 7 U.S. Cities†† Two Phases, 2014–16	Feigon and Murphy‡ 7 U.S. Cities†† 2016	Hampshire et al.** Austin, TX 2016	Alemi et al. ‡‡ California 2015	NYDOT‡‡ New York City 2017
Drive (%)	7	33	18	39	34	45	66	12
Public Transit (%)	30	22	42	15	15	3	22	50
Taxi (%)	36	10	23	1	8	2	49	43
Bike or Walk (%)	9	12	12	23	18	2	20	15
Would Not Have Made Trip (%)	8	12	5	22	1	-	8	3
Carsharing/ Car Rental (%)	-	4	-	-	24	4	-	-
Other/ Other TNC (%)	10	7	-	-	-	42 (another TNC) 2 (other)	6 (van/ shuttle)	-

* Survey question: "How would you have made *your last trip*, if TNCs were not available?"

† Survey question: "If TNC services were unavailable, *which transportation alternatives would you use for the trips* that you make using ridesourcing services?"

‡ Survey crosstab and question, for respondents that use TNCs more often than any other shared mode: "How would you make *your most frequent (TNC) trip* if TNCs were not available?"

** Survey question: "How do you currently make trips like the last one you took with Uber or Lyft, now that these companies no longer operate in Austin?"

†† The impacts in these studies were aggregated across Austin, Boston, Chicago, Los Angeles, San Francisco, Seattle, and Washington, D.C.

‡‡ These studies allowed multiple responses to the question: "How would you have made your most recent TNC trip (if at all) if these services had not been available?" Therefore, the percentages add up to more than 100 percent, making it challenging to directly compare to the other studies.

The studies show that TNC rides replace a relatively high percentage of trips among users that would have otherwise been completed by driving a personal vehicle or taking public transportation. Depending on the city, the study results also highlight taxi rides as a similar option to TNCs rides, as taxis rides would have been taken had TNC rides not been available. The studies also demonstrate TNCs' ability to increase mobility by allowing people to make trips that they would not have made otherwise.

However, some of these studies do have limitations. First, studies aggregated across multiple cities run the risk of obscuring city-specific differences in TNC impacts. Second, if respondents are asked in a general manner what transportation mode they would take in contrast to TNCs (instead of what mode they would have used for their last TNC trip), responses may be less representative of a respondent's mode replacement decision.

Key Takeaways

- The impacts of shared modes can generally be classified in terms of travel behavior, environment, land use, and social.
- The impacts of shared mobility vary by mode and local context in which it is deployed. In many cases, more research is needed to understand the contextual factors that influence the magnitude and direction of shared mobility impacts.

Understanding the Role of the Built Environment

Between 1800 and 2000, the U.S. population grew from 4 million to more than 250 million. Over this same period, the percentage of Americans living in urban areas increased from less than 5% to more than 80% (Platt et al., 2013). Today, more than eight in ten Americans live in metropolitan areas and an estimated 75% of U.S. households reside in single-family or mobile homes (Frey, 2012). Recent studies indicate that America is becoming more suburban. Between 2000 and 2010, suburban growth exceeded urban growth in 81 of the largest 100 U.S. metropolitan areas. Additionally, job centers are growing outside of urban cores and in various suburban nodes, such as "edge cities" (suburbs with high concentrations of employment density, such as office parks). One study found that employment decentralized between 1996 and 2006 with 95 out of 98 metropolitan areas decreasing the share of jobs located within three miles of downtown (Kneebone, 2016). This study also concluded that only 21% of employees in the top 98 metropolitan areas worked within three miles of downtown, while 45% worked more than 10 miles away from the city center.

Five Common Built Environment Types in the U.S.

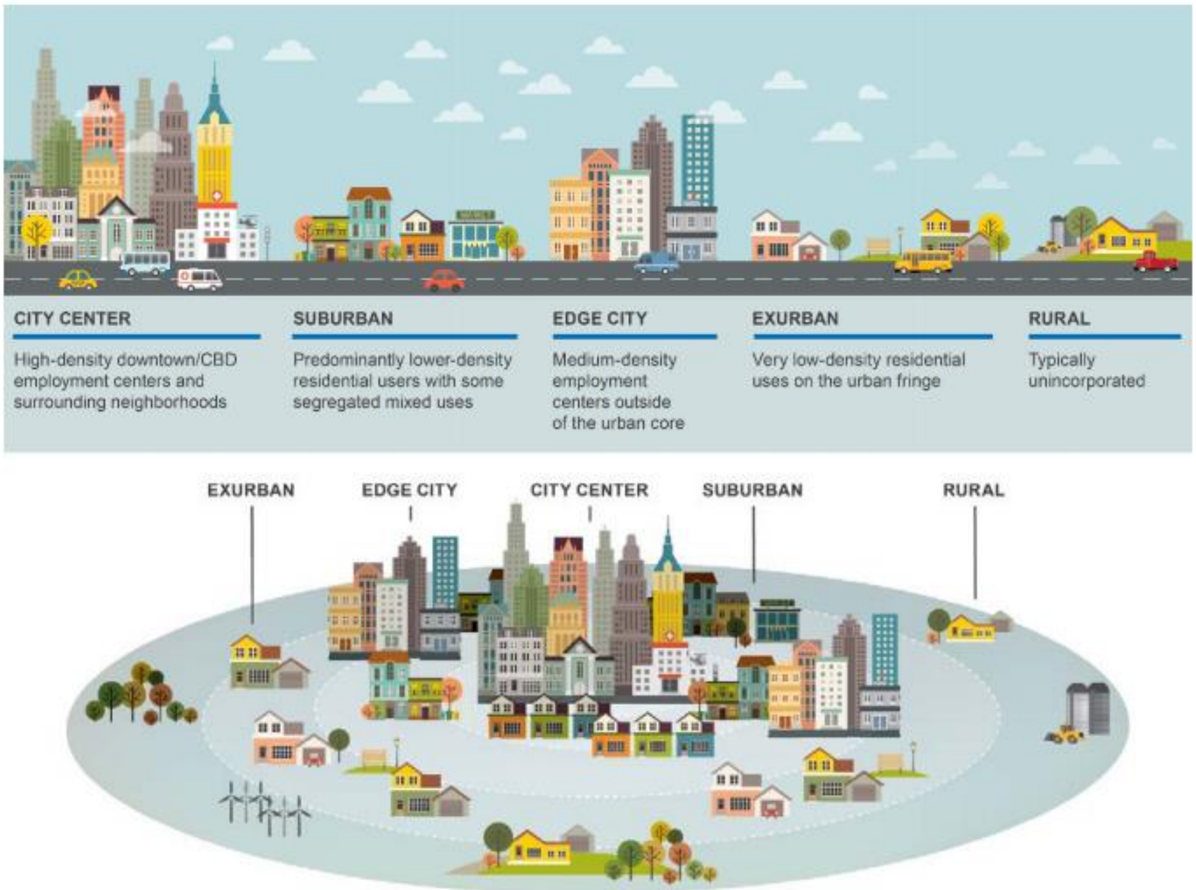
Table 8 defines five common built environments in the U.S. and common mobility challenges associated with each. Figure 6 illustrates these built environment types. The variety of urbanization patterns pose several opportunities for MOD deployment. Some of these opportunities are unique to a single built environment type, others apply to several or all built environment types.

Table 8. Common Built Environment Challenges

Built Environment Type	Definition	Challenges
City Center	A development framework with the highest concentration of jobs, comprised of Central Business Districts (CBDs) and surrounding neighborhoods.	Limited parking and loading zone capacity and peak hour roadway congestion and transit congestion.
Suburban	A less urbanized development pattern with high levels of low-density residential uses with fewer jobs than residences.	Limited or infrequent public transit service and a built environment that is more conducive to privately owned vehicles.
Edge City	An urbanization pattern presenting some features of city center employment mixed with suburban form. Edge cities are often built around highway interchanges (and occasionally around rail stations) with higher concentrations of office and retail space often paired with multi-family residences.	High congestion and a built environment not generally conducive for active transportation.
Exurban	A low-density residential development within the commute shed (area) of a larger and denser urbanized area.	Long commute distances and limited public transportation.
Rural	The lowest density development pattern characterized by low-density light industrial, agricultural, and other resource-based employment.	Long travel times between jobs, healthcare, and retail centers with limited public transportation options often necessitating private vehicle ownership.

Adapted from: Shaheen et al., 2017

Figure 6. Five Common Built Environments in the U.S.

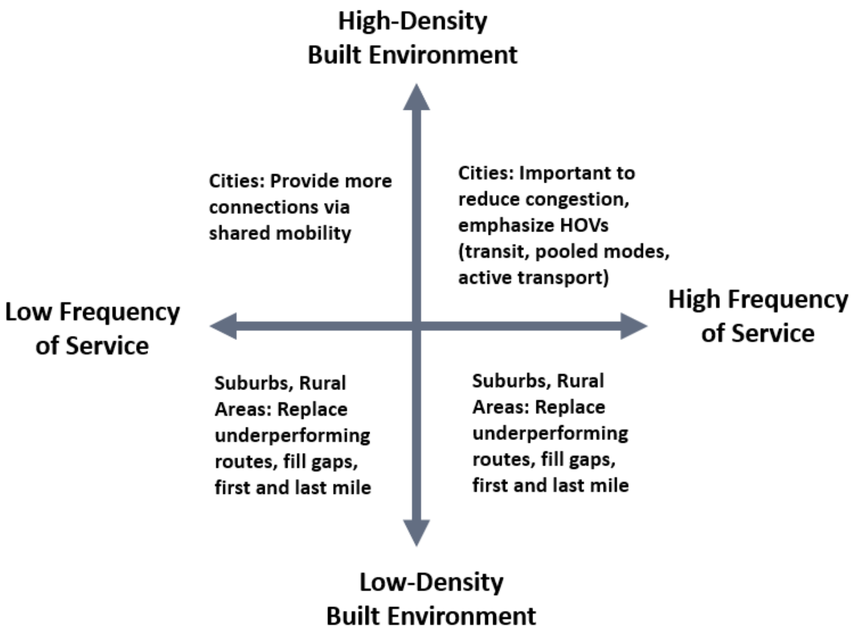


Source: Shaheen and Cohen, 2019

Shared Mobility Applications for Different Built Environments

The potential positive impacts from shared mobility can be leveraged, and the potential negative impacts mitigated, by tailoring implementation and use cases to local context. Figure 7 depicts these relationships. Shared mobility can be used in lower density-built environments with lower-frequency transit service for gap filling services, such as replacing underperforming public transit routes and first- and last-mile connections to more frequent transit service (lower left of Figure 7). In some cases, lower-density communities (i.e., suburbs and rural communities) may have public transit service that is very frequent but fiscally inefficient due to low ridership. In these areas, shared mobility could be used to augment or replace underperforming service (lower right of Figure 7). In higher-density built environments with low-frequency service, cities can leverage shared mobility to provide additional mobility options (upper left of Figure 7). Communities with higher-density built environments and more frequent public transit service can leverage shared mobility to provide additional capacity (e.g., removing people from single-occupant vehicles) and to reduce public transit congestion at peak periods (e.g., leveraging shared mobility for peak shedding) (upper right of Figure 7).

Figure 7. Environments to Implement Shared Modes



Source: Shaheen and Cohen, 2018a

Shared mobility has the potential to serve a variety of use cases depending on the built environment, such as:

- **Closed Campus Travel**: Shared mobility could provide short-distance, point-to-point travel in closed campus environments. These locations include theme parks, resorts, malls, business parks, college campuses, airport terminals, construction sites, downtown centers, real estate developments, gated communities, industrial centers and others;

- **First- and Last-Mile Connections to Public Transportation**: Traditionally, public transit has been limited by fixed routes and fixed schedules. Due to these limitations, travelers may find it difficult to complete the first- or last-mile of their journey using public transit. Shared mobility may be able to help bridge first- and last-mile gaps in the public transportation network;

- **Low-Density Service**: Shared mobility has the potential to provide "right-sized" or demand-responsive services in rural, exurban, and low-density suburban areas where low ridership may contribute to inefficient or cost prohibitive fixed route service;

- **Off-Peak or Late-Night Service**: Shared mobility may be able to augment public transit by providing service during off-peak times when long wait times may exist;

- **Paratransit**: Paratransit services could be provided by private service providers to provide additional mobility options for people with disabilities.

Table 9. Selected Use Cases for Shared Mobility Across Built Environment Types

Application of Shared Mobility to Leverage MOD	City Center	Suburban	Edge City	Exurban	Rural
Closed Campus Travel (e.g., office parks, universities, planned unit developments)		✓	✓	✓	
First- and Last-Mile Connections to Public Transportation	✓	✓	✓	✓	✓
Low-Density Service/Public Transit Replacement		✓	✓	✓	✓
Off-Peak or Late-Night Service	✓	✓	✓	✓	✓
Paratransit	✓	✓	✓	✓	✓

Key Takeaways

- A close examination of U.S. urbanization patterns shows that the built environment exists on a spectrum. Within that spectrum, five common development types exist: 1) City Center; 2) Suburban; 3) Edge City; 4) Exurban; and 5) Rural.

- Each built environment type presents different mobility opportunities and challenges for shared mobility (e.g., public transit replacement, late-night transportation, first- and last-mile connections, etc.).

Shared Mobility Implementation Policy Frameworks

To leverage the potential positive impacts and mitigate the potential negative impacts, public agencies can apply three policy frameworks:

- **Shared Mobility as an Environmental Benefit**: This framework leverages shared mobility as a way to potentially mitigate a variety of public costs associated with personal automobile use. As a result, policymakers view shared mobility as contributing to the public good and therefore justify the allocation of public resources (e.g., tax reductions, parking allocations). This framework also includes maximum government support from public agencies through the allocation of public rights-of-way through informal (or less formal) processes (e.g., direct staff review, case-by-case approvals) and waving some operations fees and paying for the installation of infrastructure needs for shared modes (e.g., signage for modes) (Cohen and Shaheen, 2016). As part of this framework, communities typically require mobility service providers to study and document local social and environmental impacts at regular intervals to justify public benefits, such as subsidies, providing electric charging stations or other alternative fuel sources, in-kind support, and the allocation of rights-of-way.

- **Shared Mobility as a Sustainable Business:** This framework considers shared mobility as a resource that can yield social and environmental benefits, while simultaneously a revenue-generating business for each operator. This view results in communities providing more limited support and infrastructure, and mobility operators are expected to carry a larger share of the operational costs (Cohen and Shaheen, 2016). As part of this framework, mobility service providers may be required to study and document local social and environmental impacts on a one-time basis or at regular intervals.

- **Shared Mobility as a Business:** This framework views shared mobility similarly to other commercial operators, thus providers bear the full costs of operations (e.g., operators pay the full cost for public rights-of-way). In this laissez-faire approach, public agencies often provide little or no support for shared mobility, and shared mobility is regulated through highly formalized processes, supply-and-demand management, and pricing that typically generates costs plus revenue for a jurisdiction (Cohen and Shaheen, 2016). In this regulatory framework, mobility service providers are not required to study or document any social or environmental impacts because they are not receiving any form of monetary or in-kind public support.

Common provisions for allocating rights-of-way, fees, permitting, signage installation, impact studies, and community engagement are summarized for each shared mobility policy framework in Table 10.

Table 10. Shared Mobility Implementation Policy Frameworks

Strategy	Shared Mobility as an Environmental Benefit (maximum governmental support)	Shared Mobility as a Sustainable Business (moderate governmental support)	Shared Mobility as a Business (minimum governmental support)
Allocation of Rights-of-Way	Jurisdictions may allocate public rights-of-way (e.g., parking, loading zones) on a case-by-case basis or through more informal processes, such as non-binding council/board of director strategies.	Jurisdictions that once allocated public rights-of-way through an informal process formalize this process.	Jurisdictions maintain a highly formalized and established process for the allocation of public rights-of-way, including a process for allocation among multiple operators.
Fees and Permits	Recognizing the social and environmental benefits of shared mobility, public rights-of-way are provided free of charge or significantly below market cost.	Fees may be based on cost recovery of providing rights-of-way associated with on-street parking (e.g., fees based on foregone meter revenue and administrative costs). In other instances, fees may be reduced to reflect environmental goals, such as charging a reduced carpooling rate for ridesharing parking.	Fees are based on a cost recovery or profit-based methodology. This could include permit costs, lost meter revenue, and administrative expenses for program management.
Signage, Markings, and Installation	Jurisdictions pay for the sign installation and maintenance, striping, and markings associated with mobility services.	Jurisdictions pay for the installation, and the operator pays for the maintenance of signage, striping, and markings.	Jurisdictions require shared operators to pay for the installation and maintenance of signage, striping, and markings.
Social and Environmental Impact Studies	Mobility providers are required to study and document local social and environmental impacts at regular intervals.	Mobility providers may be required to study and document local social and environmental impacts on a one-time basis or at regular intervals.	Mobility operators are not required to study and document any social or environmental impacts.
Public and Stakeholder Involvement	Informal process, if any, led by jurisdictions to elicit public input into the location and scaling of shared mobility within the public rights-of-way. For example, staff may internally determine the location and number of carsharing parking spaces or shared micromobility docking stations without public comment.	Informal process where the jurisdiction and service operators seek public input into the locations of mobility services through public notification and staff management of possible public concerns.	Highly formalized process where mobility operators are responsible for obtaining public input and approval on the locations of services through neighborhood councils, commissions, or formal hearings.

Adapted from: Cohen and Shaheen, 2016

Key Takeaways

- Public agencies can use three policy frameworks for shared mobility implementation. These frameworks consist of:
    - **Shared Mobility as an Environmental Benefit** that leverages shared mobility to mitigate potential negative consequences of personal vehicle use and justifies maximum public-sector support.
    - **Shared Mobility as a Sustainable Business** that leverages shared mobility as a resource that may offer environmental benefits that warrants moderate public-sector support.
    - **Shared Mobility as a Business** that views shared mobility as a business and provides limited public-sector support.

Rights-of-Way and Shared Mobility

Rights-of-way is a term used to describe the legal passage of people (and their means of transportation) along public and, sometimes, private property. Rights-of-way includes transportation infrastructure, such as streets, bicycle lanes, sidewalks, and other public and quasi-public spaces (such as an outdoor plazas). A number of communities have developed a combination of formal and informal policies to manage and allocate rights-of-way such as curbspace, loading zones, and parking for MOD (Howell et al., 2019). Many of these policies focus on:

- Allocating rights-of-way for shared mobility;
- Managing demand among multiple modes and operators;
- Determining the monetary value of rights-of-way;
- Defining a shared or on-demand service for regulation and code enforcement; and
- Addressing a variety of related administrative issues, such as enforcement, insurance, and indemnification (i.e., protection for one party against the damages and/or expenses caused by another party).

Allocating rights-of-way can also support the development of complete streets by accomodating and integrating multiple transportation modes, services, and facilities. The concept of complete streets involves a transportation policy and design approach that requires streets to be planned, designed, operated, and maintained to enable safe, convenient, and comfortable travel and access for users of all ages and abilities regardless of their mode of transportation. Complete streets vary based on community contexts but typically include multimodal infrastructure and design considerations, such as general travel lanes, bike lanes, sidewalks, frequent and safe crosswalks, accessible pedestrian signals, transit facilities and accomodations, and designated parking and loading zones.

This section provides an overview of shared mobility's impacts on rights-of-way; practices for managing and allocating rights-of-way (e.g., curbspace, loading zones, and parking); and methods for managing competition among modes and services.

Impacts of Shared Mobility on Rights-of-Way

Shared Mobility can have a number of impacts on the public right-of-way, such as:

- Increased use of parking, loading zones, and curbspace by shared modes that can create competition among modes and service providers for a limited amount of space;
- Increased modal and operator activity may also create safety hazards, such as modal conflicts and congestion in high-traffic locations; and

- Unintended impacts on vulnerable communities, such as shared micromobility, TNCs, and microtransit blocking access for people with disabilities (e.g., curbs, ramps, loading zones).

Allocating and Managing Shared Mobility in the Right-of-Way

A number of public agencies have developed a combination of formal and informal policies to allocate rights-of-way for shared mobility. Many of these policies address issues, such as: (1) how to define a particular shared mode; (2) how to allocate curbspace; (3) how to manage demand among multiple operators seeking access to the public right-of-way; (4) how to value, and potentially assess the cost of, rights-of-way; and (5) how to manage administrative issues, such as permits, snow removal, curb and street cleaning, parking enforcement, and signage. Aside from these strategies, formally allocating rights-of-way for shared mobility – such as carsharing parking; shared micromobility pick-up and drop-off locations; loading zones for microtransit and TNCs; and delivery services – is another common way communities provide access to mobility services.

When allocating rights-of-way, communities may consider: 1) service characteristics, 2) procedures for allocating, 3) methodologies for valuing rights-of-way, and 4) managing competition among operators and modes. Table 11 summarizes these various considerations.

Table 11. Considerations in Rights-of-Way Allocation

Considerations	Description
Service Characteristics	• Business models (e.g., for-profit, nonprofit, hourly rentals, membership-based services)
Procedures for Allocating Rights-of-Way	• Jurisdiction (e.g., city staff, city council, parking authority) • Process (e.g., first-come, first-serve; lottery; auction; request for proposal or pilot)
Methodology for Valuing Rights-of-Way	• Cost recovery of program administration • Foregone meter, permit, and other revenue • Supply and demand (e.g., auctions) • For profit (e.g., generate revenue for local coffers)
Management of Competition	• Methods for managing competition between operators • Methods for managing competition between modes • Method for dispute resolution (e.g., administration hearings and appeals, mediation, arbitration, litigation)

Source: Adapted from Cohen and Shaheen, 2016

Managing the rights-of-way for curbspace, loading zones, and parking is generally implemented through policies that:

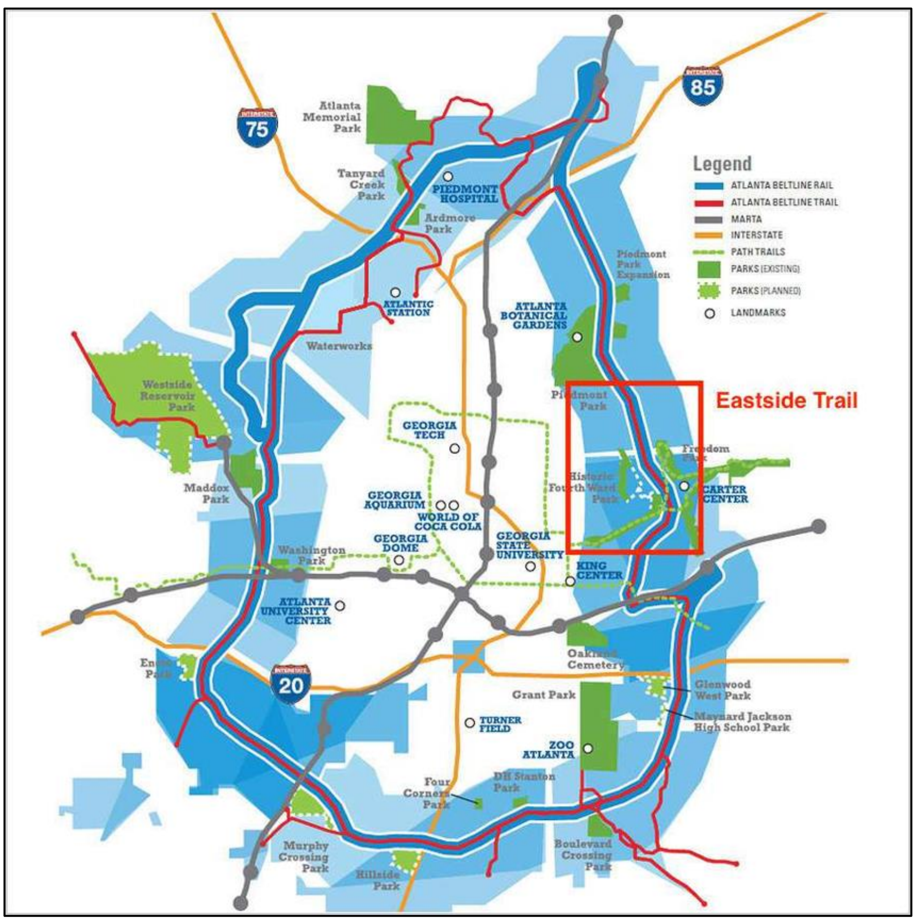
- Develop a process for access and use of the public rights-of-way;
- Identify permits that should be issued or fees that should be charged for mobility operations in the public rights-of-way;
- Establish standards for signage and/or markings to identify proper parking areas for vehicles and devices (e.g., bicycles and scooters);

- Enforce loading and parking compliance through virtual geographic boundaries (commonly referred to as geofencing) using GPS, radio frequency identification (RFID), or other technologies; and
- Employ data sharing requirements and/or require impact studies as a condition for allowing services to use the public rights-of-way.

Adapting Infrastructure for Active Transportation and Shared Micromobility - Atlanta, GA

In tandem with allocating rights-of-way for shared mobility through policies, communities can adapt infrastructure for active or low-speed modes. Atlanta, Georgia is redeveloping 22-miles of abandoned railroad rights-of-way into a 33-mile network of planned, multi-use trails known as the Atlanta BeltLine (shown in Figure 8). The BeltLine was initially intended to be used by pedestrians, joggers, and bicyclists. Micromobility devices, such as dockless scooters and e-bikes, are now also allowed to operate on the BeltLine, but at restricted speeds. The BeltLine demonstrates how jurisdictions can adapt and repurpose existing rights-of-way for walking, cycling, bikesharing, scooter sharing, and other low-speed modes (Atlanta BeltLine, 2019).

Figure 8. Atlanta BeltLine



Source: Samuel J. Keith, n.d.

Table 12 details rights-of-way management strategies for curbspace, loading zones, and parking along with examples and example policies.

Table 12. Rights-of-Way Management Strategies

	Curbspace	Loading Zone	Parking
Issue	Shared mobility, particularly shared micromobility devices, have the potential to impede curbspace access, particularly for pedestrians and people with disabilities. Curbspace management presents an opportunity to mitigate this challenge.	Shared modes (e.g., TNCs, carsharing, last-mile delivery) may require more frequent loading and unloading of passengers and packages. This could create modal conflicts with cyclists and people with disabilities. This requirement may result in the need for spatial and temporal policies that manage loading zones or changes to the physical infrastructure.	Dedicating parking for carsharing may be controversial (particularly when converting existing parking dedicated to privately owned vehicles). However, by allowing more users to share a vehicle, carsharing may be able to expand parking access to a greater number of users.
Sample Policy	Separate curbspace into different zones based on their characteristics and functions and use this division to inform micromobility parking policies.	Expand existing loading zones or create new ones to allow for easier loading and unloading of packages and passengers by MOD modes.	Reserving parking spaces exclusively for shared modes, such as carsharing.
Example	The Seattle Department of Transportation (SDOT) classifies curbspace into three zones: 1) Frontage zone (adjacent to buildings); 2) Landscape/furniture zone (area between roadway curb face and the front edge of the pedestrian clear zone); and 3) Pedestrian clear zone (between the previous zones, open for pedestrian travel). SDOT requires micromobility devices to be parked in the landscape/furniture zone and they cannot intrude into the pedestrian clear zone.	The San Francisco Municipal Transportation Agency (SFMTA) Commuter Shuttle Program has developed a network of loading zones and stops for commuter shuttles in an effort to reduce conflicts between commuter shuttles operated by local institutions and companies and the SFMTA Muni transit system (Bialick, 2014). The stops are dispersed throughout the city and use of them requires shuttle operators to comply with a list of regulations developed by the SFMTA and payment of a use fee (SFMTA, 2017b).	In 2014, the Portland Bureau of Transportation (PBOT) revised its carsharing parking policy and developed an auction system to distribute parking spaces to carsharing operators. PBOT annually compiles a list of available on-street, metered parking spots carsharing operators can use. Operators can then bid on the spaces, with bids starting at the combined cost of lost meter revenue, installation, maintenance, and administrative expenses.

Other resources for curbspace rights-of-way allocation can be found in the Institute of Transportation Engineers' Curbside Management Practitioners Guide.

Curbspace Management at Airports

Allocating rights-of-way and curbspace at airports requires unique policy, regulatory, and implementation strategies because airports may be limited by federal and state regulations (i.e., federally-funded airports can only levy taxes and fees if they are used for airport related purposes). Generally, these taxes and fees are for cost-recovery and cannot generate a profit. TNCs and carsharing services are disrupting traditional methods of landside revenue generation and airports are increasingly levying taxes and fees to allocate rights-of-way and manage congestion from shared mobility (e.g., TNCs). These fees may be part of a tiered congestion pricing strategy where some locations (e.g., terminal curb side, reserved areas of parking garages) are priced differently than others. A few actions that airports can potentially leverage to improve curbspace management and address declining landside revenue due to modal shifts include:

- Designating TNC loading zones in un- or under-used areas of the airport (e.g., top floors of parking garages, surrounding parking lots);
- Leveraging higher fees for TNC vehicles that pick-up and drop-off riders closer to airport terminals, rather than at nearby loading zones; and
- Requiring service providers to obtain permits to provide service within airport jurisdictions.

Methods for Managing Competition Among Services

The increasing number of transportation modes and service providers is creating an increased demand for limited curbspace and rights-of-way. Some methods that can be used to manage competition among modes and operators when considering the allocation of public rights-of-way are summarized in Table 13.

Table 13. Methods Used to Address Competition Among Operators

	Description	Advantages and Disadvantages	Example
First-Come, First-Serve	A public policy where requests for public rights-of-way by private operators are attended to in the order in which they arrive	*Advantages:* No need to develop more sophisticated policies, particularly when there is only one requester *Disadvantages:* Policy may give preferential treatment to market incumbents; new entrants may have difficulty getting access to the same resources if those resources are taken by an earlier requester	In August 2017, Miami-Dade entered a partnership with Zipcar, a carsharing company that already operated in the area, to provide carsharing services at mobility hubs located at five different Metrorail stations (Department of Transportation and Public Works, 2019).
Lotteries	A public policy where requests for rights-of-way are selected by random drawing	*Advantages:* Generally perceived as fair *Disadvantages:* Excludes other potentially mitigating factors that may warrant preferential or disadvantageous treatment to further the public good	Seattle issues taxi medallions by lottery to drivers meeting minimum requirements for driving experience, driving record, and conduct (City of Seattle, 2019).

	Description	Advantages and Disadvantages	Example
Auctions	A public policy where requests for rights-of-way are granted to the highest bidder	*Advantages:* Raises money for municipal coffers and establishes market rate pricing for public rights-of-way *Disadvantages*: Equity issues may occur where operators with greater financial resources can outbid operators with fewer financial resources; costs may be passed onto the carsharing consumer	Portland holds an annual auction between carsharing operators for parking spots, with the highest bidder receiving preferred access to spaces designated by the city (Lempert, 2018).
Preferential Treatment	A public policy that gives preferential treatment to a specific mobility operator for a particular reason	*Advantages:* Allows a public agency to incentivize certain behaviors or characteristics *Disadvantages:* Requires careful planning and legal review to ensure policy is fairly implemented	After reviewing 12 applications as part of a competitive process, the San Francisco Municipal Transit Agency (SFMTA) granted two scooter sharing companies (Scoot and Skip) permits to operate a fleet of 625 scooters in August 2018 (Hawkins, 2018b).
Collaborative Approaches	A public policy employing a collaborative process, such as negotiation or mediation, in an attempt to reach a mutually beneficial outcome	*Advantages:* Brings all stakeholders together to possibly obtain a mutually beneficial outcome *Disadvantages:* Not all parties may be willing to have an open dialogue	In 2014, Seattle gathered representatives from TNC, taxi, and labor stakeholder groups to develop a compromise policy that removed the limit on the number of TNC drivers and increased the number of taxi licenses.
Requests for Proposals	A solicitation, often through a bidding process, by a public agency or government interested in procuring a shared mobility service	*Advantages:* Gives public agencies and local governments greatest control to select the service characteristics and requirements they desire *Disadvantages:* Potentially time consuming and susceptible to litigation if not properly executed	In December 2018, Kansas City issued a request for proposals from standing electric scooter operators specifying the "ideal" program characteristics, including lessons learned from an interim ordinance governing dockless e-scooters.
Tandem Policies	A public policy where every stakeholder receives an equal share of the public rights-of-way	*Advantages:* Generally perceived as fair *Disadvantages:* May not be appropriate for vastly different scales of MOD services to give large and small operators the same allocation	Bay Area Rapid Transit (BART) provides three carsharing companies (Gig, Getaround, and Zipcar) two parking spaces per company per BART station. The fee for each space is the same as a monthly parking pass ($30-$115.50 per month, depending on the station).

Source: Adapted from Cohen and Shaheen, 2016; Horowitz et al., 2014; Viken et al.

Key Takeaways

- An increasing number of shared modes and operators can impact the rights-of-way in a number of ways. Potential adverse impacts can be mitigated through strategies that manage and allocate rights-of-way access among service providers.
- Rights-of-way policies can be broadly categorized into curbspace, loading zones, and parking policies. These categories can help communities develop and implement more targeted rights-of-way management strategies.
- When allocating rights-of-way, communities may consider service characteristics and procedures for allocating and valuing rights-of-way and managing competition among operators and modes.

Incentive Zoning

Parking can be a major expense for communities and developers, with spaces costing upwards of tens of thousands of dollars to construct. Integrating shared mobility into existing and new developments offers an opportunity to expand transportation options and reduce the need for, and cost of, parking. Communities can implement an array of policies aimed at easing zoning regulations and parking minimums to promote the inclusion of shared mobility in new developments (Cohen and Shaheen, 2016). Commonly referred to as incentive zoning, these policies can be categorized as:

- Policies that reduce required parking for the inclusion of shared mobility, and
- Policies that increase development density for the inclusion of shared mobility.

Parking reduction policies are ideal in urban areas with particularly high housing or parking construction costs. This strategy can help make housing more affordable by reducing per-unit costs and can encourage neighborhood redevelopment and revitalization by making it easier for developers to have positive cash flows and higher capitalization rates on real estate projects. Similarly, parking substitution (i.e., replacing general-use parking with parking for shared modes) can be employed in both new and existing developments (Cohen and Shaheen, 2016).

Policies that allow increased density generally include greater floor-to-area ratios, more dwelling units permitted per acre, and greater height allowances. Similar to parking reduction, policies that allow for increased density aim at making development more lucrative for developers and real estate investors. Rather than reducing per-unit or overall project costs, these policies increase the overall cash flow of development projects. Allowing increased density is most appropriate for cities seeking to increase overall urban density, residential density, or both. These strategies can be particularly effective at encouraging brownfield redevelopment because these parcels are often more expensive to repurpose due to the costs commonly associated with environmental remediation (Cohen and Shaheen 2016).

Incentive Zoning – Indianapolis, IN

In 2016, Indianapolis adopted a revised consolidated zoning and subdivisions ordinance (Indianapolis 2016). As part of the city's zoning code, developers will be permitted a cumulative reduction in required parking of up to 35 percent. The code includes the following shared mobility-related parking reductions:

- Shared vehicle, carpool, or vanpool spaces: The minimum number of required off-street parking spaces may be reduced by four for each shared vehicle, carpool, or vanpool space provided. Each shared space counts toward the minimum number of required parking spaces.
- Electric-vehicle charging stations: The minimum required off-street parking may be reduced by two parking spaces for each electric-vehicle charging station provided. Each charging station counts toward the minimum number of required parking spaces.
- Bicycle parking: For every five bicycle parking spaces provided in excess of the required bicycle parking spaces (or where no bicycle parking is required), the minimum number of required off-street parking spaces may be reduced by one or up to a maximum of five.
- Proximity to public transportation: The minimum number of off-street parking spaces required for any development may be reduced by 30 percent, if the developer builds within a quarter mile of a sheltered public transit stop or public transit corridor. The minimum number of off-street parking spaces required may be reduced by 10 percent, if the development is between a quarter mile and a half mile of a stop or public transit corridor.

Reprinted from Cohen and Shaheen, 2016; City of Indianapolis, 2019

While incentive zoning policies can be codified into local codes, it can also be granted on a case-by-case basis through variances. Variances are a process where applicants, such as developers, request a deviation from standard building and zoning codes (Cohen and Shaheen, 2016).

Key Takeaways

- Parking reduction or substitution to reduce required parking for developments can support the use of shared mobility.
- Allowing increased urban densities for real estate projects that incorporate shared mobility can also support increased use of shared mobility.

Multimodal Integration

Multimodal integration can improve connectivity and traveler convenience, helping reduce traveler reliance on private vehicles. Multimodal integration can be achieved through the physical co-location of mobility services, integrated fare payment across modes, and information integration, such as trip planning apps and multimodal aggregators. Each of these are discussed in the context of policies and practices in the following sections.

Please be aware that FHWA publishes a Fostering Multimodal Connectivity Newsletter to provide transportation professionals with real-world examples of strategies for multimodal transportation. The goal is that these investments will promote economic revitalization, provide access to jobs, and achieve safer communities through support of accelerated project delivery, technology and design innovation, and public-private partnerships. The newsletter communicates FHWA and partner efforts in support of the USDOT Strategic Plan for improving connectivity, accessibility, safety, and convenience for all users.

Physical Integration

Fundamentally, physical integration is about providing places where people can make seamless connections between travel modes (e.g., shared mobility, public transportation, etc.). Co-locating services (both passenger mobility and goods delivery) and public transportation can create a network effect that can multiply the effectiveness of MOD. MPOs and other public agencies have begun developing best practices to encourage mobility hubs and transit-oriented developments (TOD) around transportation nodes (Federal Highway Administration, 2018b; Federal Transit Administration, 2015a). Although similar in approach, TOD focuses on increasing density around corridors and mobility hubs with the goal of increasing transit ridership and shared mobility use (Cervero and Dai, 2014). Mobility hubs present an opportunity to equitably integrate shared mobility and TOD (Anderson et al., 2017). The Broward Metropolitan Planning Organization has developed mobility hub typologies comprising of:

- **Gateway Hubs** that have a high number of boardings and disembarkings, are surrounded by high-density mixed-use areas, and serve at least two high capacity transit lines;
- **Anchor Hubs** that have a moderate to high number of boardings and disembarkings, are surrounded by employment centers and major institutions, and serve at least one high capacity transit line; and
- **Community Hubs** that serve more local trips than regional trips and serve local bus routes.

Source: Broward Metropolitan Planning Organization, 2009

Table 14 provides key characteristics that are typically included with most mobility hubs and potential actions public agencies can take to implement these characteristics (Broward Metropolitan Planning Organization, 2009; SANDAG, 2017).

Table 14. Mobility Hub Key Features and Potential Actions for Physical Integration

	Characteristic	Description	Potential Action
Station Design	**Art and Architecture**	Creates sense of place through art and architectural elements	Collaborate with community organizations to develop unique art and architecture
	Waiting Areas	Offers well-lit, partially enclosed waiting areas	Use community input to design waiting areas that feel safe and comfortable
	Mobile Retail	Provides mobile retailers or delivery services to enhance station	Partner with businesses who already offer, or are interested in offering, these services
	Aesthetic Fit	Fits with the surrounding environment	Partner with local businesses and property owners to increase development around transit hubs
Station Access	**Activity Access**	Provides access to housing, jobs, entertainment, and other activities	Partner with local institutions to promote transit use
	Accessibility	Accessible and navigable for people with a wide range of capabilities	Work with accessibility-focused organizations to ensure accessibility
	Walkability	Provides crosswalks and walkways for pedestrian safety	Prioritize pedestrian safety and use of space, rather than vehicle use
	Rideability	Allows for station access via electric powered micromobility devices	Ensure that walkways are wide enough to safely accommodate rideable devices (e.g., hoverboards, electric scooters)
	Bikeability	Offers biking infrastructure	Promote the use of biking through the provision of biking infrastructure (e.g., bike storage, pathways)
	Flexible Curb Management	Allows for variety of uses of curbspace from multiple modes	Design curbs with flexible use in mind, prioritizing safety for all users (e.g., pedestrians, public transit, freight, TNCs)
	Smart Parking	Uses technology to provide real-time parking information	Implement technology-based systems to monitor parking capacity
Shared Mobility	**Shared Micromobility**	Access to station-based or dockless modes	Supplement existing transportation options with bikesharing and scooter sharing options
	Charging	Offers charging stations for micromobility and electric vehicles	Partner with local programs for flexibly designed charging stations
	Carsharing	Alleviates vehicle ownership responsibilities by sharing vehicles	Implement permitting process that delineates carsharing parking areas and practices

	Characteristic	Description	Potential Action
	Carpooling	Divides vehicle ownership costs between riders	Offer carpooling incentives, such as carpool-only parking
	For-Hire Services	Offers curbspace for TNCs and Taxis	Partner with TNCs to provide on-demand ridesharing services
	Microtransit	Vehicles that accommodate five to 12 people for local service provision	Partner with local microtransit providers to enhance service coverage
	Neighborhood Electric Vehicles	Provides low-speed, low emission transportation mode for local areas	Accommodate neighborhood vehicle design needs in station design
Service Provision	**Public Transportation**	Serves local and regional public transportation routes and lines	Co-locate services together to increase accessibility
	Service Frequency	Offers frequent service and timed transfers	Locate stations at multi-route intersections to increase connectivity
	Real-Time Information	Broadcasts real-time route information	Use telecommunication technology to provide up-to-date travel information to riders
	Integrated Fare Payment	Offers single fare payment for multiple modes	Integrate fare payment system between all modes of transportation

Sources: Espino, 2016

Public agencies may consider:

- **Co-locating services together** to create mobility hubs and encourage the use of shared mobility.
- **Increasing density around mobility hubs** to develop TOD and increase transit ridership and shared mobility.
- **Implementing potential actions** to support the physical integration of services.

Information Integration

Increasingly, consumers are engaging in multimodal decision-making based on a variety of factors including cost, travel time, wait time, number of connections, convenience, environmental impact, and other attributes. Rather than making decisions between modes, mobility consumers can make decisions among modes, "modal chaining" to optimize route, travel time, and cost. Information integration, such as multimodal aggregators and trip planners can enhance traveler access to trip planning and real-time travel information across multiple modes.

Trip Planners and Multimodal Aggregators

Smartphone apps are transforming mobility by enhancing access to traveler information. In recent years, more travelers are using trip planners and multimodal aggregators to: 1) search routes, schedules, near-term arrival predictions, and connections; 2) compare travel times, connection information, distance, and costs across multiple routes and modes of transportation; and 3) access real-time travel information across multiple modes. A number of communities, such as Dallas, Texas and Denver, Colorado have developed websites and smartphone apps to allow users to plan and pay for multimodal trips. In Europe, another service, UbiGo, has piloted MaaS by bundling and repackaging transportation services through a single platform. Table 15 describes how these platforms vary in level of integration and services offered.

Table 15. Multimodal Planners and Policy Considerations

App Type	Program, Agency	Location	Summary	Policy Consideration
Public Transit App	GoPass, Dallas Area Rapid Transit (DART)	Dallas, TX	Multi-agency trip planning and fare payment app to allow riders to transfer between modes and offer time-based passes (e.g., daily, monthly).	Public agencies can use apps to promote use of, and transfer between, transportation modes for riders. These apps can also be used for data collection and piloting new projects and initiatives (e.g., fare options).
Mobility Aggregator	Uber Transit, Regional Transportation District (RTD)	Denver, CO	RTD is partnering with Uber Transit allowing transit connections to be planned and tickets to be purchased within the Uber app.	Public-private partnerships employed in apps can assist in bridging transportation service gaps and improving transfers.
MaaS	UbiGo	Stockholm, Sweden	App-based subscription service to multiple transportation modes within the city, users pay monthly fee for the services used.	Agencies can encourage the aggregation of transportation services and make them available through a single platform to encourage the use of these services.

Public agencies may consider:

- **Providing real-time and updated information** to proprietary or third-party apps and websites to allow riders to use this information for their trip planning and trip completion purposes.
- **Developing websites and smartphone apps** that integrate trip information to allow riders to plan their trip using real-time information and between mobility modes.
- **Using application programming interfaces[4] (APIs)** to integrate applications from transit agencies with existing apps and service providers, such as shared mobility companies.

[4] An application programming interface (API) is a set of routines, protocols, and tools for building software and applications. APIs can help developers and smartphone apps share data and information between apps and make it easier for third-parties to develop apps and incorporate features from existing apps.

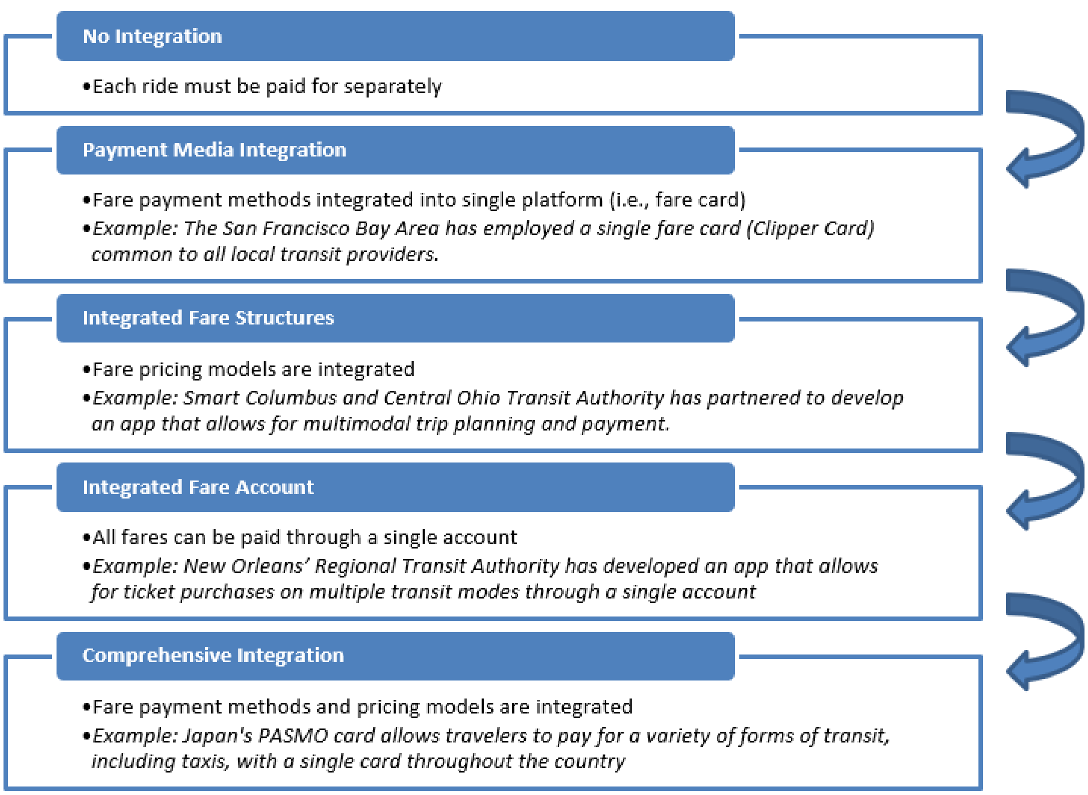
Integrated Fare Payment

Integrated fare payment offers an opportunity to provide increased traveler convenience for multimodal connections. Benefits of fare payment integration can include:

- Increasing user satisfaction;
- Promoting the use of public transportation;
- Bridging first-and last-mile gaps in the transportation network;
- Providing additional modal transportation options;
- Reducing costs for riders; and
- Quicker modal transfers.

Figure 9 defines five levels of fare payment integration (from no integration to comprehensive integration).

Figure 9. Integrated Fare Payment Types

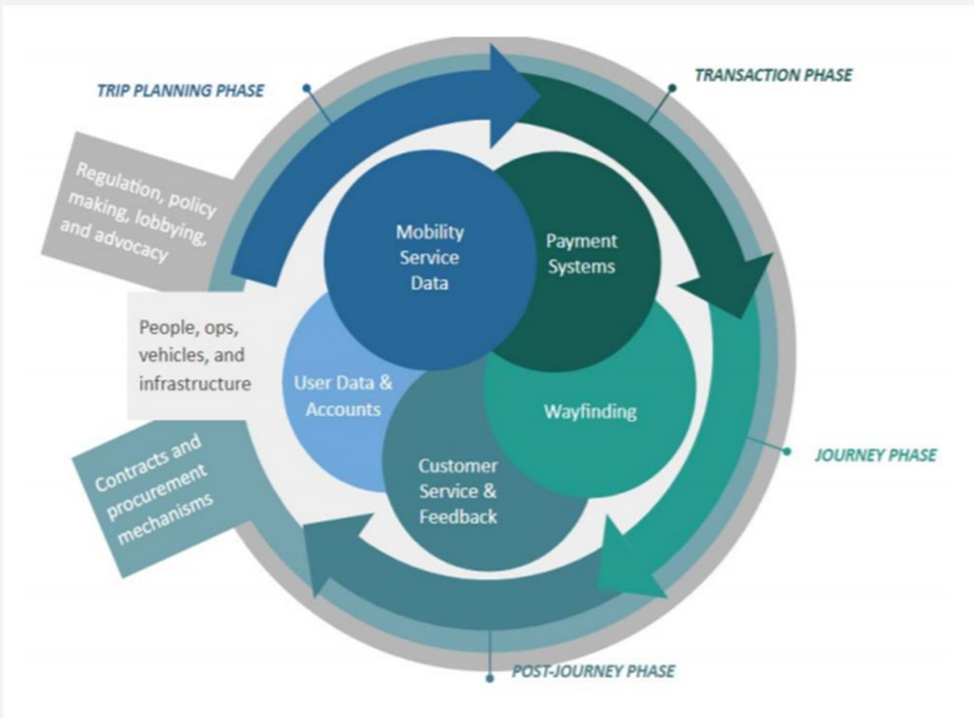


Source: Shaheen, Cohen, Broader, Davis, and Farrar, 2019

California Integrated Travel Project (Cal-ITP) – California

The California State Transportation Agency (CalSTA), Caltrans, and intercity rail and local transit agencies are partnering together in an effort to develop an easy, accessible transportation and payment system throughout California through the California Integrated Travel Project (Cal-ITP). Cal-ITP was established to help the state reach its goals of: increasing ridership, improving travel experience, reducing transportation costs for riders and operators, and mitigating negative environmental impacts. The project seeks to seamlessly integrate four travel phases: trip planning, transaction, journey, and post-journey. Figure 10 illustrates Cal-ITP's integration plan. The main goal of Cal-ITP is to develop a collaborative statewide, state-supported fare payment system by leveraging regulation, policy, advocacy, and procurement processes through statewide stakeholder collaboration.

Figure 10. Cal-ITP Service Design



Source: Rebel Transit and Ticketing B.V. and DB Engineering and Consulting USA Inc., 2019

Public agencies may consider:

- **Creating a common payment method**, such as a fare payment card, to provide riders with a uniform method of fare payment for multiple modes.
- **Creating a common account** to allow all fares to be paid through a single digital account.

- **Exploring potential partnerships** to assist in capitalizing upon existing assets (e.g., common payment card) or partnering with third-party payment providers (e.g., Apple Pay).
- **Interagency cooperation** to establish a common pricing model that is sustainable for all agencies.
- **Integrating new systems with existing systems** so fare payments (e.g., common payment card) can be used to pay for other existing systems.
- **Expanding** integrated fare payment systems to a larger geographic region to provide seamless transfers between public and private mobility modes.

Source: Rich, 2013; California Integrated Travel Project, 2018

Key Takeaways

- Transportation services can be co-located and integrated into their surrounding environments to create mobility hubs.
- Trip planners and multimodal aggregators can assist users with multimodal trip planning and decision-making during a traveler's journey.
- Integrated fare payment provides the opportunity for enhanced customer convenience with varying levels of integration from basic integration (e.g., payment media integration) to comprehensive integration.

Last-Mile Delivery

In recent years, last-mile delivery services for food and small packages have grown rapidly due to technology advancements, changing consumer patterns, and a growing consumer recognition that goods delivery can serve as substitutes for personal trips to access goods and services. Together these trends are transforming the retail sector from "just in time inventory" where retailers order inventory and stock shelves on an as-needed basis, to "just in time delivery" with goods delivered directly to consumers on demand (Shaheen and Cohen, 2018b).

Personal Delivery Vehicles - Singapore

Singapore's Land Use Authority (SLA) faced opposition from food couriers after banning the use of e-scooters on sidewalks. As a result, the SLA is now offering $5.1 million (USD) in grants to help food couriers pay for power-assisted bicycles (Coconuts Singapore, 2019).

The following section highlights innovations in last-mile delivery and the potential impacts this could have on broader traveler behavior.

Last-Mile Delivery Innovations

Last-mile delivery can be provided by traditional logistics providers (e.g., UPS, FedEx, DHL); retailers (e.g., Amazon); or CNS (e.g., Postmates, UberEats). Last-mile delivery can be paired with other technologies to secure packages (e.g., delivery lockers, in-vehicle delivery, and in-home delivery). Table 16 summarizes these innovations in last-mile delivery.

Amazon Fresh

Amazon recently eliminated the fee for its grocery delivery service (Amazon Fresh) for Amazon Prime members. This decision was driven by increased competition from other last-mile delivery services and companies, such as InstaCart and Kroger (Valinsky, 2019).

Table 16. Last-Mile Delivery Innovations

Type	Definition	Examples
Courier Network Services (CNS)	CNS provide for-hire delivery services for monetary compensation to businesses or consumers via an online platform (such as a website or smartphone app). CNS have the potential to create a network of on-demand delivery options.	Deliv UberEats Postmates
Locker Delivery	Locker delivery allows consumers to have packages delivered to a self-service locker at home, work, public transit stations, or another location. Locker delivery can help consumers, merchants, and delivery services overcome a variety of challenges, such as concerns about package security or the need for a person to receive a delivery.	Amazon Hub UPS Access Point
Mobile Warehousing	Low-cost, mobile trailers can offer flexible warehouse space to allow supply chain managers to meet changing demand. Mobile warehousing can help meet delivery times and disperse inventory and avoid challenges, such as weather disruptions and pricing volatility.	United States Postal Service
Micro Warehousing	Micro warehouses are small-scale facilities that can be integrated into the supply chain and are used to keep goods closer to the consumer to help reduce delivery times.	Albertsons Kroger Walmart
Subscription Delivery Service	Subscription delivery services allow consumers access to low-cost, flat-rate deliveries (e.g., Amazon Prime, Shop Runner). Due to the low-cost and typically unlimited deliveries, subscription services may contribute to induced demand for last-mile delivery, however more research is needed.	Amazon Prime Shop Runner

Private companies have begun to develop and implement a variety of delivery applications. In response, public agencies are implementing pilots and policies. A few notable developments are highlighted in Table 17.

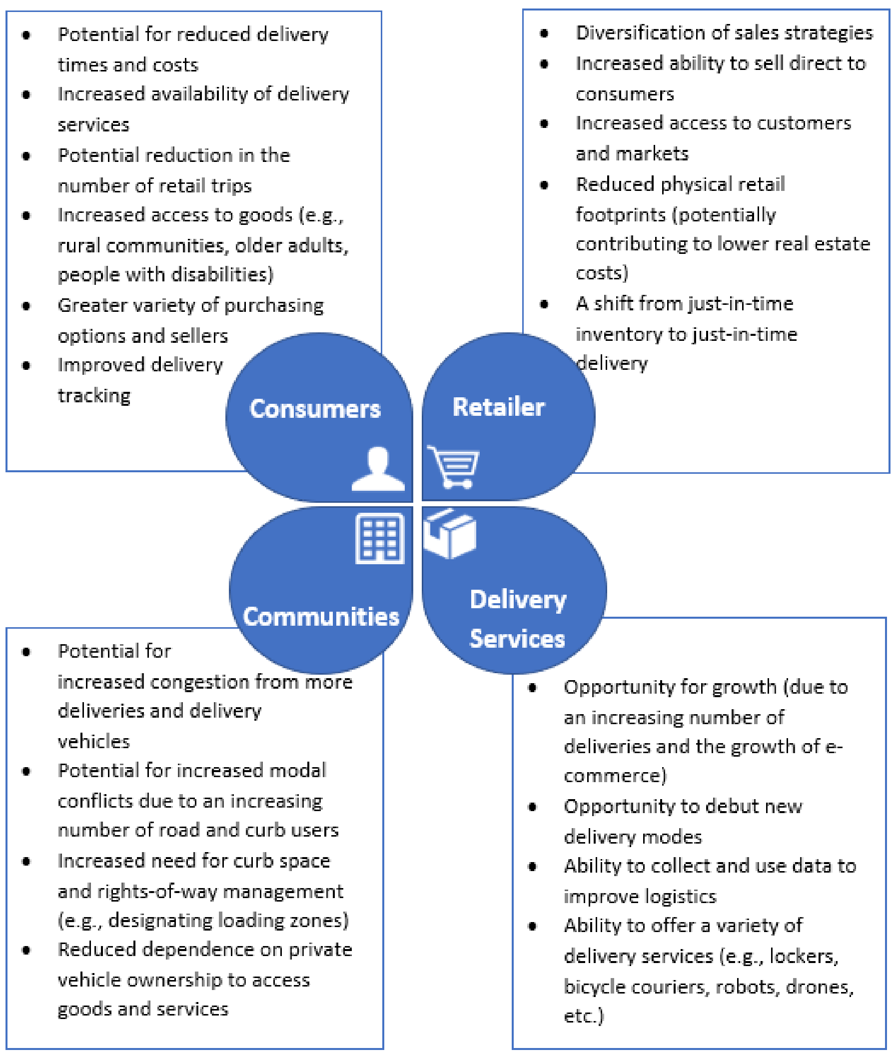
Table 17. Last-Mile Delivery Innovations in Practice

Type	Organization - Location	Implementation Examples
Courier Network Services (CNS)	San Francisco Municipal Transportation Agency – San Francisco, CA	The San Francisco Municipal Transportation Agency (SFMTA) is conducting a survey of CNS providers to study the potential impacts of various delivery methods on the transportation network. A few focus areas for SFMTA include: compliance with the agency's safety and congestion principles, equitable access to delivery services, and the use of clean vehicles (San Francisco County Transportation Authority, 2018). The goal of the study is to identify potential strategies to these challenges (Barnett; 2018).
Locker Delivery	Amazon Lockers – West Sussex, England	In 2012, Amazon signed a contract with West Sussex, England, to place Amazon lockers in three of the county's largest libraries. The goal was to place the lockers at highly visible public facilities with good lighting and security. The lockers have provided a revenue source for the libraries and are used by 80 to 100 people per week (Holsenbeck, 2018).
Mobile Warehousing	Albertsons - USA	Albertsons, an American grocery chain, is beginning to redevelop their stores to include mobile warehousing areas to support the company's online grocery shopping service (KPS Global, 2019).
Micro Warehousing	United States Postal Service - USA	In 2014, the United States Postal Service (USPS) began offering micro warehousing to support logistic services. The service leverages USPS's processing, retail, and transportation network to support e-commerce (United States Postal Service, 2014).
Subscription Delivery Service	Family Dinner – Boston, MA	Family Dinner is a local grocery subscription delivery service operating in Boston, Massachusetts. A study by Heard et al. (2019) found that meal kits can reduce transportation and refrigeration emissions as well as packaging waste.

Last-Mile Delivery

There is a wide range of stakeholders involved in, influenced by, or affected by these innovations in last-mile delivery. Figure 11 highlights the roles of four key stakeholders in the last-mile delivery chain: 1) Retailers, 2) Consumers, 3) Delivery Services, and 4) Communities.

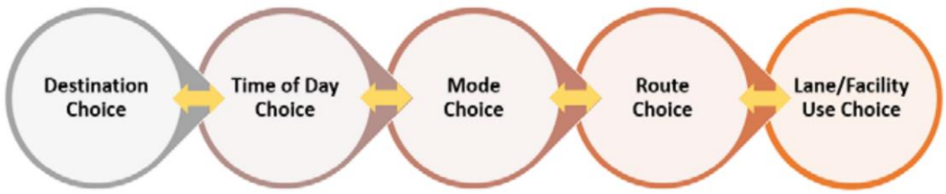
Figure 11. Potential Stakeholder Impacts



Source: Keyes, 2017; Chammas, 2019; GreenBiz Research Study, 2017; Datex, n.d.; Federal Highway Administration, 2018a

Changes in last-mile delivery are contributing to broader shifts in travel behavior. Figure 12 depicts the series of "what, where, when, and how" decisions that impact transportation demand and system use. The growth of digital and on-demand goods delivery could substitute some in-person trips and create demand for additional delivery trips depending on consumer behavior. For example, a traveler's decision to change their consumption preferences from driving to the mall on the way home from work versus having goods delivered to them could change their trip generation behavior.

Figure 12. Decision Making Factors in Travel Behavior



Source: Shaheen et al., 2017

Changes in travel behavior due to new delivery methods may result in subsequent impacts on communities. These impacts may include the presence of new delivery methods, increased number of delivery vehicles and modes, and increased use of last-mile delivery services. In order to accommodate these impacts public agencies may consider:

- **Designating space for delivery lockers at mobility hubs** and other venues to offer additional goods delivery capabilities in communities (Edrington et al., 2017, 33-37).
- **Developing regulations** such as size/load restrictions, emissions requirements, and parking reservation systems so delivery vehicles have prioritized access to a loading zone, rather than cruising until a loading zone becomes available (Civitas, 2015; DePillis, 2019; Glasco, 2018; Hsu, 2019).
- **Implementing pricing** policies to manage the potential impacts of last-mile delivery (e.g., time-of-day pricing for deliveries during peak periods, etc.) (Civitas, 2015).
- **Partnering with academic institutions and non-government organizations (NGOs)** to study the impacts of last-mile delivery services (UPS, 2017; Ivanov et al., 2019).
- **Engaging and educating** stakeholders, such as businesses, public agencies, delivery services, and local residents on the opportunities and challenges of innovations in last-mile delivery (UPS, 2017; Haag and Hu, 2019).

Key Takeaways

- Innovative technologies and business models are helping to reimagine service delivery.
- In recent years, delivery services have grown rapidly due to changing consumer patterns that have transformed the retail sector from "just in time inventory" to "just in time delivery."
- Delivery services may result in a variety of impacts, such as competing for rights-of-way access, increasing congestion, and disrupting trip chains.

CHAPTER 5: MOD Implementation Considerations

This chapter discusses MOD implementation considerations for data sharing and management, including how data is commonly used and concerns with the use of data. MOD data is important for measuring and evaluating pilot projects and informing decisions within the MOD ecosystem on both the demand and supply sides of the marketplace. This chapter also discusses the potential impacts of MOD on transportation labor and on equity within the transportation network. MOD presents an opportunity to enhance transportation equity by providing a greater variety of transportation options; however, MOD may also present a number of equity challenges as well.

MOD Data Sharing and Management

Collecting, storing, sharing, and analyzing MOD data can be challenging for a variety of stakeholders. This section discusses common uses of MOD data, challenges collecting and using data, and potential practices to overcome these challenges.

Sharing Data

- **Establishing Data Standards –** Standardized data can help facilitate data sharing between public agencies and other stakeholders. Data standards can be established by identifying useful data, determining suitable data forms, and requiring two-way data sharing when possible. Data standards include the type of data desired (e.g., shared mobility trips originating or terminating at public transit stops) and the data format (e.g., General Bikeshare Feed Specification [GBFS]).

Municipal Open Data Policy – Las Vegas, NV

Las Vegas has established an open data initiative with the goal of informing the public of available resources and increasing government transparency. The Open Data Steering Committee governs the initiative, ensures that real-time data is available in a usable format through an online portal, and provides annual status reports on the initiative (City of Las Vegas, n.d.).

- **Providing Open Data** – The public and private sectors can develop policies to encourage data sharing. Open data (i.e., publicly available information for download and re-use) may be released real-time or at periodic intervals. Open data can aid service providers in creating smartphone apps and integrating multiple shared modes. For example, Austin, Texas shares dockless micromobility data monthly through its open data website.

- **Forming Data Exchanges –** The public and private sectors, academia, and standards organizations (e.g., Institute of Electronic and Electrical Engineers [IEEE], SAE International, ITS JPO), can develop data exchanges to facilitate data sharing. Data exchanges can be public facing or for internal agency use only. Internal data exchanges may contain sensitive information intended for use by a limited number of parties. Public facing data exchanges, on the other hand, are intended to provide the broader public with open information.

Common Uses for MOD Data

Stakeholders can use data to better understand the impacts of MOD on travelers, society, and the environment. Common uses for MOD data include:

Trip Planning

- **Integrated Trip-Planning and Payment** – The public and private sectors can disseminate real-time data about their services (e.g., vehicle locations, service cost, and availability) and integrate data into apps that can help travelers plan, navigate, and pay for trips (Gettman et al., 2017). Integrated payment cards (e.g., California Bay Area's Clipper card) can be used to pay for multiple modes during one trip and help facilitate multimodal trip planning (Desouza and Smith, 2016).

Transportation Planning

- **Agency Transportation Service Planning** – Public agencies can examine performance metrics, such as response times (the time from customer request to pick-up or goods delivery) and service areas, to identify and respond to spatial and temporal service gaps. Identifying these gaps may allow agencies to more efficiently deliver services through targeted use cases and partnerships. Operational characteristics may include geographic area of service, times of operation, and demographics served.

- **Performance-Based Transportation Planning** – Data can be used to identify appropriate strategies to integrate MOD considerations into performance-based transportation planning. For example, data identifying TNC hotspots can be used to plan infrastructure (e.g., loading zones) to support MOD. Refer to the FHWA's Performance Based Planning and Programming Guidebook for more information and examples on using performance goals, measures, and targets to guide transportation investment and policy decisions.

Transportation Service Performance Compliance

- **Service Auditing and Enforcement** – Public agencies can use data for compliance purposes (e.g., ensuring compliance with wheelchair accessible vehicle requirements, fleet size, or vehicle/device parking locations) (Deshais, 2019). For example, public agencies can monitor mobility service providers, such as TNCs, to evaluate how many vehicles within a fleet are accessible to people with disabilities.

- **Service Effectiveness and Accounting** – Public and private sector organizations can analyze transportation operations data (e.g., origin-destination pairs, travel time, or vehicle occupancy) to evaluate the performance of the service and the behavior of users. For example, mobility services can be compared to traditional fixed-route service to compare trip times between modes. For public agencies, traveler fare or cost data can be used to monitor revenue, costs, and subsidies.

Common Concerns with MOD Data Management and Sharing

The use of data can raise a number of policy and privacy issues. Numerous studies indicate that people are either unaware of what private information they are exposing or they do not understand what information they are consenting to share (Miller, 2014). As of November 2019, 31 states have established laws regulating the secure destruction or disposal of personal data, such as financial information (Help Net Security, 2019). Common concerns associated with data management and sharing include:

Data Privacy

- **Traveler Privacy** – Apps may intentionally or unintentionally collect an array of sensitive and personally identifiable information (PII), such as location history, email addresses, phone numbers, financial information, usage history of the apps installed on their phone, and mobile Internet browsing history (Shaheen et al., 2016; D'Agostino et al., 2018).

- **Private Sector Trade Secrets** – Mobility or goods delivery service providers may generate or rely on proprietary information, such as information on business strategies, trade secrets, or other sensitive material (e.g., passenger matching, and vehicle dispatch and routing algorithms) (Shared-Use Mobility Center, 2019). Proprietary data can be important to a company's business plan or growth strategy raising concerns about what type of data is shared, particularly if it is subject to release under public records laws if a private provider is receiving public funding or partnered with a public agency.

- **Public Records Laws** – Data used by a public agency may be subject to public records requests (Kimley-Horn and IBI Group, 2019). This can present a challenge to public agencies seeking to protect traveler privacy or company trade secrets. Private companies may be reluctant to share data with public agencies because it may cause the data to become a public record and subject to public release (Kimley-Horn and IBI Group, 2019). Concerns over personal and proprietary data should be considered to balance the interests of the public sector, private companies, and records requesters (Dickey, 2019).

Intelligent Transportation Systems Joint Program Office DataHub

The USDOT's Intelligent Transportation Systems Joint Program Office (ITS JPO) established the ITS DataHub as a data exchange for the USDOT's publicly available ITS data. By creating the ITS DataHub, the ITS JPO hopes to encourage third-party research that investigates the effectiveness of emerging ITS technologies, development of apps, and increasing compatibility of datasets. The ITS DataHub is home to over 100 datasets that are stored based on their classifications (e.g., emerging data sets are stored in sandbox testing environments to allow flexibility with their use). The ITS DataHub has information on a variety of topics including connected vehicle data, incident data, and travel times, and data is quality-checked, well-documented, and free.

Public Sector-Specific Issues

- **National Transit Database (NTD) Formula-Based Funding** – When public transit agencies receive financial support from the FTA, they are required to report their data through the National Transit Database (NTD) (GAO, 2018). However, the FTA does not require MOD trip characteristic data to be reported when appropriating funding (GAO, 2018).

- **Staff Capability Constraints** – Public agencies may lack the staff expertise, technical resources, and/or funding to develop an in-house capability to handle, store, and analyze the large volumes of data shared by mobility providers (Shaheen et al., 2016).

Data Standards, Management, and Security

- **Data Security** – Handling and storing data can present a security risk for data managers (Shaheen et al., 2016). Security risks can include security breaches, data theft, and cyber espionage (D'Agostino et al., 2019).

- **Lack of Universal Data Standards and Reporting Requirements** – Service providers may provide data about their service in a non-standardized format (Shared-Use Mobility Center, 2019). This can create challenges for service providers generating data in different formats for different partners and for public agencies trying to analyze data from multiple sources.

Examples of MOD Data Standards

Providing standardized and open data allows public agencies to understand the impacts of transportation modes, identify transportation network gaps, and offer multimodal, real-time information through a variety of platforms. A few data standards include:

- General Bikeshare Feed Specification (GBFS): A common data format that provides real-time, operational bikesharing data, but excludes historical data and PII;

- General Transit Feed Specification (GTFS): A common data format typology that public agencies can use to publish transit schedules and geographic information in order to make the data accessible to a wide variety of software programs; and

- Mobility Data Specification (MDS): A data standard and application programing interface (API) that can be used by cities to gather, analyze, and compare real-time and historical data from shared mobility providers. MDS includes data such as mobility trips and routes, location and status of vehicles/equipment (e.g., available, in-use, out-of-service), and service provider coverage areas.

Overcoming Common Issues with MOD Data

The practices for managing MOD data are still evolving. Table 18 summarizes common issues and potential practices to address data privacy, security, standardization, and other concerns.

Table 18. Potential Practices for Addressing Common Issues with MOD Data

	Common Issue	Potential Practices
Data Privacy	Traveler Privacy	• Aggregate and summarize data allowing it to be analyzed while protecting traveler information.[e] • Educate app users how their data will be used and shared and all associated risks with such practices.[e] • Require smartphone apps for travelers to offer an opt-in consent process that allows travelers to choose what data they wish to share (e.g., billing information, travel history, search history, etc.). Opt-in consent processes give users more transparency and control over the type and extent of information they share with third parties.[e] • Require mobility providers to remove PII from their data prior to sharing the data with a public agency.[e]
Data Privacy	Public-Private Data Sharing	• Require mobility providers and app-based platforms to share data that are not proprietary or personally identifying as a condition for receiving an operating permit within the jurisdiction.[c] • Third-party organizations, such as universities, can act as “data brokers” to serve as an intermediary to manage and anonymize data before providing it to public agencies or the general public. This can help mitigate risks associated with public records laws and concerns about the release of user or proprietary data.[f] • Reserve the right to share data with researchers and other jurisdictions for research and review in the public interest, in line with established practices for cybersecurity.[e] • Public agencies and private companies can be conscious of requesting and sharing sensitive records that could be subject to release if shared to the public sector or through public-private partnerships. Public-private partnerships or data sharing agreements can clearly define the data that can be shared while addressing business and individual privacy concerns.[e]
Data Privacy	Public Records Laws	• Treat location-based mobility data as PII in policy and internal practice. Develop or update protocols for handling, storing, and protecting such data, and include policies for handling public disclosure requests that account for the private nature of this data.[e] • Allow reported data to be available to the public.[d]
Data Privacy	Data Aggregation	• Data (e.g., population density, land use, time span for collection) can be aggregated before it is shared publicly as open data.[e] • Aggregate location-based data before it is committed to storage. • Data can be aggregated to higher levels as the population in an area decreases (or in residential contexts, or during off-peak hours).[d] • Data can include metadata with key methodological information on how data items were collected.[d]

	Common Issue	Potential Practices
Security and Data Standardization	Data Security	• Adopt standards-compliant digital security methods and protocols for storage, retention, and deletion; data theft or breach plans; and cybersecurity insurance. Carefully consider the potential application of experimental technologies, such as blockchain.[bg] • Ensure that data security policies and practices are reviewed regularly and updated, if needed.[e] • Encourage vehicle manufacturers, parts suppliers, mobility software developers, and all stakeholders who support transportation to follow best practices and industry standards for managing cyber risks in the design, integration, testing, and deployment of connected mobility technologies.[d] • USDOT-approved projects can apply for access to the Department's Secure Data Commons (SDC) platform. SDC provides a secure platform for sharing and collaborating on research, software tools, algorithms, and analysis involving sensitive datasets.[a]
	Lack of Universal Data Standards and Reporting Requirements	• Coordinate with private partners and other public agencies to adopt standardized data formats, such as General Transit Feed Specification (GTFS) or Mobility Data Specification (MDS).[d] • Promote standardized, open data formats among transportation providers to ensure data sharing and management is more consistent and predictable.[d] • Consult with the USDOT agencies (e.g., ITS JPO, FTA) on additional guidance for how MOD trips should be defined under public transportation statutes and any data reporting requirements for mobility providers.[c]
Public Sector-specific Issues	National Transit Database	• Retain MOD data to inform future plans and maintain summarized data in the NTD database. The Government Accountability Office (GAO) has indicated that the USDOT is moving towards expanding NTD reporting requirements to include passenger MOD services (Shared-Use Mobility Center, 2019).[a]
	Staff Capability Constraints	• Maintain in-house capability through positions, such as a chief technology officer or chief data officer, to oversee data interoperability, data security, and data sharing agreements.[g] • Coordinate across agencies to establish best practices for public agencies and private companies to retain individual trip records for the shortest time needed and to share methods for applying, analyzing, aggregating, and anonymizing MOD data.[d]

[a] GAO, 2018

[b] HBS Digital Initiative

[c] Kimley-Horn and IBI Group, 2019

[d] Kilm et al., 2016

[e] Shaheen et al., 2016

[f] Shared-Use Mobility Center, 2019

[g] U.S. Department of Transportation, 2019

Blockchain and MOD

Blockchain is a form of secure data storage where the information is stored in a distributed manor by a variety of organizations, so that no single entity stores all of the data pertaining to a series of transactions. Although this technology has been used primarily for digital currencies and financial transactions, the technology could have applications for MOD (Shaheen et al., 2018). MOD blockchain use cases could include securing automated and connected vehicles, increasing transparency and efficiency in freight supply chains, and removing the need for intermediaries in peer-to-peer shared mobility (Rajbhandari, 2018; Choe et al., 2017). For example, a blockchain-based carsharing network could potentially allow for owners to rent their cars on a short-term basis at a lower transaction cost than current peer-to-peer carsharing companies that currently require payment to a marketplace intermediary for facilitating the transaction.

Key Takeaways

- MOD data sharing and management can present a number of challenges, such as:
    - Protecting traveler privacy and private sector trade secrets,
    - Complying with public records laws,
    - Reporting MOD data in the National Transit Database,
    - Limited staff capability of handling data,
    - Securing data, and
    - Lack of universal reporting standards.
- A few strategies for overcoming common MOD data management and sharing include establishing universal reporting standards, aggregating data, and protecting personally identifiable information.

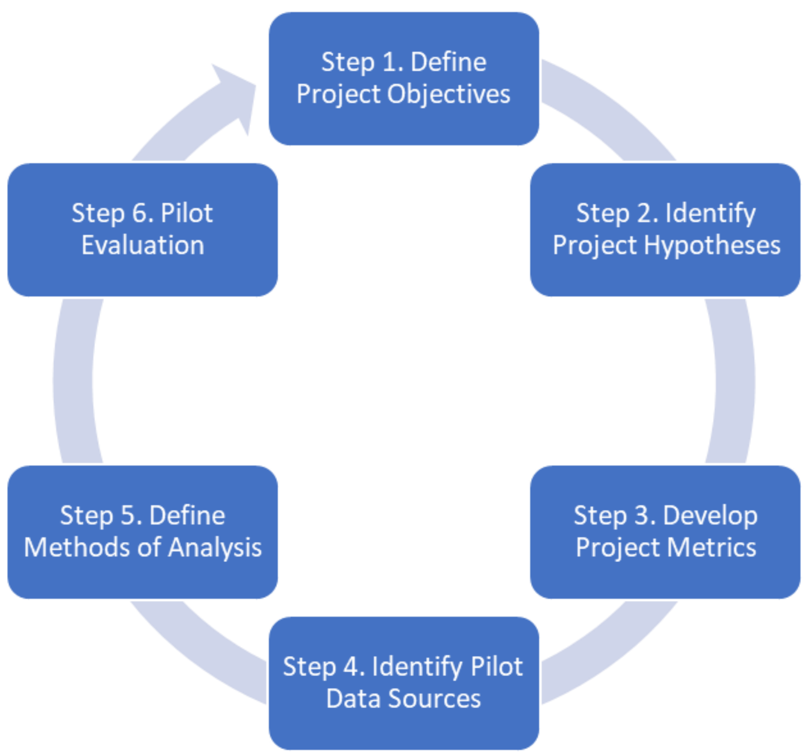
MOD Pilot Projects

Pilot projects serve as a venue for evaluating public policies and regulations that could either support or hinder MOD. Public agencies at the federal, state, regional, and local levels can provide funding for MOD pilot projects to help the public sector prepare for and implement innovations, validate their technical and institutional feasibility, and measure the impacts of specific programmatic deployments. This section provides a framework that agencies can use to evaluate MOD pilots, maximize the potential for success, reduce the risk of failures, monitor results, and adapt, if necessary (Shaheen et al., 2019).

Measuring and Evaluating the Impacts of MOD Pilot Projects

With the evaluation of a MOD pilot project, there can be utility in establishing an evaluation framework that can guide the formulation of questions, define metrics for measurement, and identify data sources. Figure 13 outlines a six-step pilot design and evaluation framework that can serve as a general process to develop and evaluate MOD pilot projects.

Figure 13. MOD Pilot Project Design and Evaluation Framework



Adapted from: Shaheen et al., 2019

Step 1. Define Project Objectives

In this step, a public agency defines the objectives of a MOD pilot project. For example, project objectives could include "reducing average travel times for rural commuters" or "reducing regional transportation system-related GHG emissions by 30% within seven-years".

Step 2. Identify Project Hypotheses

The next step is for public agencies to develop hypotheses that can be tested as part of the evaluation process (e.g., "the average travel time of the population using bus route 30 will decrease when using this bus route").

Step 3. Develop Project Metrics

After the objectives and hypotheses have been defined, performance metrics should be determined. Performance metrics can be used by a variety of local and regional stakeholders, and when comparable metrics are used, public agencies can evaluate the effectiveness of multiple MOD pilot projects. Developing project metrics can also be useful in identifying data sources and gaps. Examples of some performance metrics that could be used for MOD pilots are included in Table 19. These metrics may require a before-and-after analysis to identify if an improvement has been made.

Table 19. Sample MOD Transportation Performance Metrics

Category	Hypothesis/Research Question	Sample Performance Metrics
Safety	Have pedestrian injuries and fatalities declined?	Injuries or fatalities per 100,000 pedestrians
Congestion	Is congestion getting worse?	Travel time to work in minutes
Public Transit Ridership	Is public transit ridership increasing?	Public transit trips per person
Equity	Is the transportation network equitable?	Average trip time for people with disabilities before service change and after service change
Goods Delivery	How long are delivery vehicles occupying loading zones?	Idle parking time in the loading zone in minutes

Adapted from: Shaheen et al., 2017; Ivanov et al., 2019

For additional metrics, please refer to [Understanding how cities can link smart mobility priorities through data]().

Step 4. Identify Pilot Project Data Sources

During this step, a public agency defines data sources needed to evaluate project performance metrics and works with project partners to develop data sharing and data use agreements. When data limitations are encountered, using alternative data collection methods or proxies may be considered. For example, TNC vehicle occupancy can be approximated based on reported national averages, trends, or surveys.

Step 5. Define Methods of Analysis

In this step, a public agency defines the methodologies that will guide data analysis. Advanced models or statistical analyses are not always required, certain metrics can be evaluated by aggregating or plotting data to find averages or basic trends. Qualitative evaluation methods, such as expert interviews or rider interviews and shadowing, may also be appropriate.

Step 6. Pilot Project Evaluation

The final step is for a public agency to conduct the evaluation using the planned evaluation methods. Data to evaluate the project can be obtained through a review of performance metrics, agency and rider interviews, and other data collection techniques. Results of the evaluation will be used to validate the pilot project's hypotheses. Lessons learned from the evaluation can influence the next iteration of pilot testing through a reconsideration of the project's approach to satisfying the project objectives. Findings should be documented and shared with peer communities and public agencies for feedback.

Funding for MOD Pilot Projects

Public agencies at the federal, state, regional, and local levels can provide funding for MOD pilot projects. In 2016, FTA provided $8 million to 11 recipients through the MOD Sandbox Program to enhance transit industry preparedness for MOD. The pilot projects focused on incentive strategies, TNCs for first- and last-mile connections to public transportation, integrated bikesharing, carpooling and ridesharing, data interoperability, on-demand paratransit, and multimodal apps and payments. FTA anticipates funding additional pilot projects through the Integrated Mobility Innovation (IMI) and Accelerating Innovative Mobility (AIM) programs.

Federal Transit Administration's MOD Sandbox Program

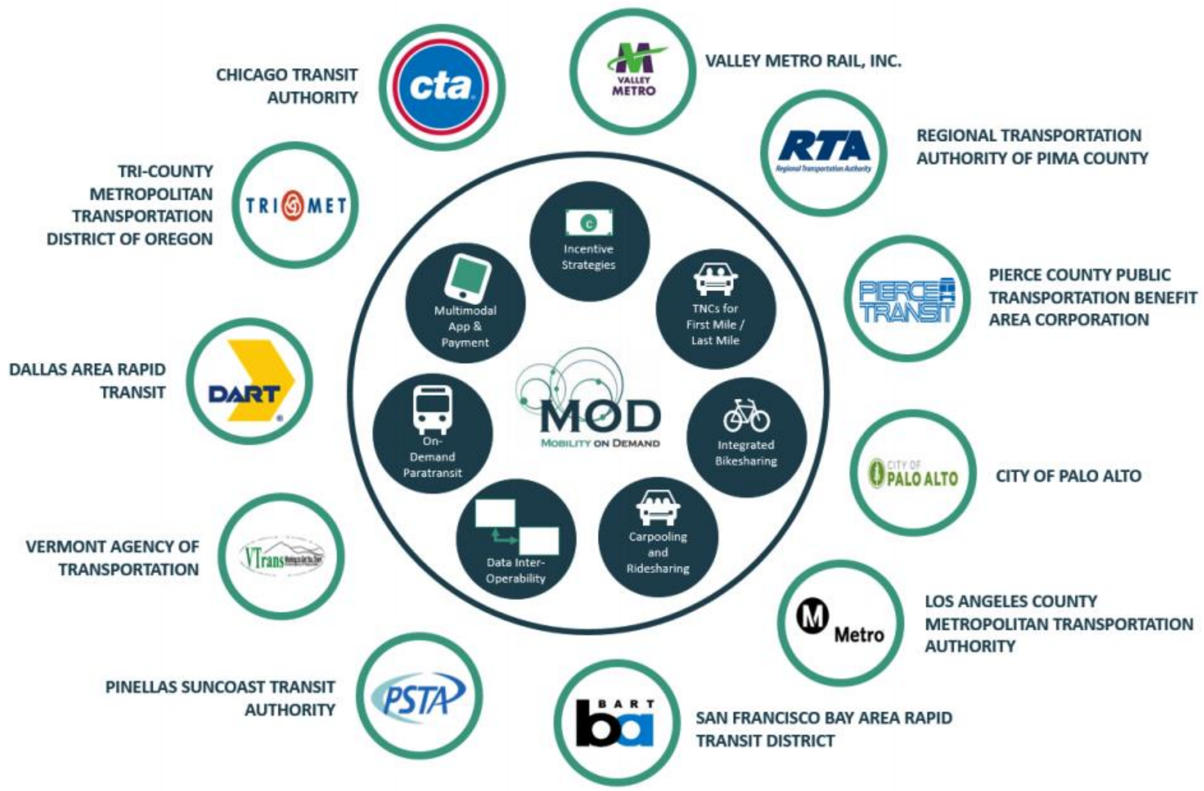
The FTA's MOD Sandbox Program provides a venue where MOD concepts and strategies, supported through local partnerships, are demonstrated in real-world settings. Key goals of the MOD Sandbox include:

- Improving transportation efficiency by promoting agile, responsive, accessible, and seamless multimodal service inclusive of transit through enabling technologies and innovative partnerships.
- Increasing transportation effectiveness by ensuring that transit is fully integrated and a vital element of a regional transport network that provides consistent, reliable, and accessible service to every traveler.
- Enhancing the customer experience by providing each individual equitable, accessible, traveler-centric service leveraging public transportation's long-standing capability and traditional role in this respect.

Eleven MOD Sandbox grantees are piloting a variety of MOD use cases and enabling technologies, such as smart phone trip planners, first- and last-mile programs using shared mobility, and paratransit service using innovative demand-responsive technologies. The MOD Sandbox Independent Evaluation, a review of the performance and impacts of the MOD Sandbox projects, will be completed in 2020. Early lessons learned from the MOD Sandbox demonstration sites include:

- Some public transit agencies liked the ability to name partners without a traditional procurement method, while others would have preferred to issue a request for proposal to solicit prospective vendors.
- Public agencies and private sector partners were ambitious in their initial MOD project designs. This resulted in the rescoping or downscaling of many pilot projects.
- Several public agencies noted challenges in working with private vendors, particularly related to contracting and data agreements. In some cases, partners were unable to agree to terms. In others, partners employed a range of techniques to more narrowly tailor data sharing requests to include: less frequent reporting, more aggregate data reporting, and higher levels of geo-spatial data to protect consumer and proprietary vendor information.
- A number of public agencies expressed ongoing concerns about the reliability of private sector partners, such as 1) partners that overpromised and underdelivered; 2) partners that promised data but were unwilling to share sufficient data for the public agency to report key data metrics to FTA; and 3) partners whose business models evolved through the course of the pilot projects, causing project continuation after the MOD Sandbox deployment to be challenging.
- Some project sites reported challenges transitioning from the Sandbox demonstration to regular post-demonstration service because of the drug and alcohol testing currently required for federally funded initiatives.
- Identifying sustainable business models and partnerships is key to enabling the continuation of successful programs post pilot.

Figure 14. MOD Sandbox at a Glance



Source: USDOT, 2018

Federal Transit Administration's Integrated Mobility Innovation (IMI) Program

FTA's Integrated Mobility Innovation (IMI) Program funds projects that demonstrate innovative and effective practices, partnerships, and technologies to enhance public transportation effectiveness; increase efficiency; expand quality; promote safety; and improve the traveler experience. FTA's 2019 IMI funding opportunity provides $20.3 million for demonstration projects focused on three areas of interest: Mobility on Demand, Strategic Transit Automation Research, and Mobility Payment Integration to:

- Explore new business approaches and technology solutions that support mobility,
- Enable communities to adopt innovative mobility solutions that enhance transportation efficiency and effectiveness, and
- Facilitate the widespread deployment of proven mobility solutions that expand personal mobility.

In March 2020, FTA announced the selection of 25 projects in 23 states to receive funding under the IMI Program. FTA received 104 eligible project proposals totaling approximately $107 million.

Federal Transit Administration's Accelerating Innovative Mobility (AIM) Program

FTA's Accelerating Innovative Mobility (AIM) Program will provide $11 million in challenge grants to help transit agencies experiment with new ways of doing business, such as exploring new service models that provide more efficient and frequent service. The AIM Program will advance transportation innovation by promoting forward-thinking approaches to finance, system design, and service. FTA announced a Notice of Funding Opportunity for the AIM Program in March 2020.

Key Takeaways

- Pilot projects provide an opportunity for public agencies to test innovations, validate the feasibility of deployments, and measure the impacts of services, and also serve as a venue for evaluating public policies that could impact MOD.
- A six-step project design and evaluation framework can be used as a general process to develop and evaluate MOD pilots. Six key steps include: 1) Define Project Objectives; 2) Identify Project Hypothesis; 3) Develop Project Metrics; 4) Identify Pilot Data Sources; 5) Define Methods of Analysis; and 6) Pilot Evaluations.

MOD and Labor

The growth of MOD is changing traditional labor roles, creating new employment opportunities, and disrupting incumbent industries. This section discusses the various impacts of MOD on labor and other stakeholders and considerations for overcoming potential labor challenges.

Impacts of MOD on Labor

MOD is contributing to employment growth in some sectors of transportation, such as increased demand for CNS, TNCs, and microtransit drivers. However, MOD is also disrupting existing employment where demand for other services have declined, such as taxis and liveries (Cohen and Shaheen, 2016). In addition to changes in the number and types of jobs available, MOD is also disrupting traditional labor practices, often contributing to the growth of part-time, flexible schedule, and independent contractor work (Hall and Kruger, 2016). Key MOD labor issues typically include:

- **Worker-Company Relationship:** App-based workers may be classified as employees or independent contractors which can impact a worker's compensation, taxes, and benefits. Generally, an individual is considered an independent contractor if the payer has the right to control or direct only the result of the work and not what will be done and how it will be done. Typically, a person who performs services for an employer is considered an employee if the employer can control what will be done and how it will be done (i.e., dictating the nature of the work and how it is completed) (Gould, 2017);

- **Benefits:** Depending on their employment classification, transportation workers may be eligible for different benefits (e.g., overtime pay, health insurance);

- **Wages:** In many jurisdictions, mobility service providers may not have a minimum wage, reducing the cost of services for consumers but also contributing downward wage pressure on incumbent modes (e.g., taxis);

- **Skills:** MOD is impacting the skills, number of employees, and job classifications in the transportation sector (e.g., cashless payments through smartphones allow public transit agencies to phase out farebox cash handlers);

- **Training:** As MOD evolves, staff may need to be retrained or new staff may need to be hired with different skillsets (e.g., public agencies may need to hire data analysts); and

- **Emerging Positions:** MOD can create new job classifications (e.g., personnel that rebalance and/or recharge shared micromobility fleets) (Charge Ahead California, 2012).

Connected and automated vehicle applications will likely continue to impact the types of jobs and skills required for labor in the future.

Key Stakeholders in the Labor Impacts of MOD

There are a variety of labor stakeholders, such as regulators, mobility service providers, workers, and unions. These stakeholders include:

Regulators

- **Federal government** defines "employee" and "independent contractor" classifications in the National Labor Relations Act. Federal protections for employees pertaining to wages, hours, and other working conditions may also be implemented through federal legislation and regulation, such as income, Social Security, Medicare, and unemployment taxes paid to the Internal Revenue Service by employers.

- **State, airport, and local authorities** establish regulatory requirements, such as background checks and liability insurance for mobility service providers, employees, and independent contractors within their jurisdictions. Issues states typically regulate include: insurance, driver licensing, motor vehicle registrations, livery laws, and volunteer protections. In the absence of statewide regulation, local authorities may establish their own labor regulations (Ashbaugh, 2003). In some jurisdictions, airport authorities may be granted unique authority to regulate MOD, including labor-related issues and contracts.

Service Providers

- **Supply chain managers** provide long-distance goods delivery and shipping and face long-term impacts from automated long-haul trucks. Federal regulation regarding the role of human drivers in automated trucks is under development. State regulations for human drivers vary, complicating inter-state trucking. The USDOT regulates the number of hours drivers can work and the minimum amount of time drivers must spend resting between shifts. For example, drivers can work a maximum of 60 hours over seven consecutive days with a required 10 hours off duty per day.
- **Mobility service providers** maintain their own hiring practices, typically classifying most workers as independent contractors for many job classifications.
- **Public transit agencies** typically rely on represented (i.e., unionized) and unrepresented (i.e., non-unionized) employees to provide their services. Public transit agencies receiving federal funds must provide certain benefits to their employees, such as health insurance and retirement options.[5]
- **Taxi companies** are encountering competitive pressure from TNCs and other demand responsive services that may be regulated differently.

[5] Protections for public transportation workers in public transit agencies that receive federal funds are set forth in 49 USC § 5333(b), also known as Section 13(c) of the Federal Transit Act.

Represented and Non-Represented Workers

- **Public transportation unions** represent workers and may negotiate compensation, benefits, and working conditions of drivers, attendants, and other represented staff. The role of unions varies by state based on labor laws and collective bargaining agreements. Section 7 of the National Labor Relations Act defines conditions in which unions can legally organize strikes.
- **Taxi driver unions** may represent taxi drivers, offer dispute resolution, organize strikes, and offer collective bargaining representation. Taxi unions may also work with regulatory agencies to negotiate wages, working conditions, regulated fares, and labor standards.
- **Non-unionized workers** do not have a bargaining representation and cannot strike. However, non-unionized workers may request benefits from employers or organize fellow workers to discuss workplace conditions.

Labor Issues and Policy Considerations

The impacts of MOD on labor affect stakeholders in a variety of ways. Table 20 provides an overview of issues and policy considerations for each stakeholder.

Table 20. Labor Issues and Policy Considerations

Stakeholders		Issues	Potential Actions
Regulators	State, Airport, and Local Authorities	• TNCs typically benefit from less restrictive regulations than taxis, limousines, and liveries in most jurisdictions (Shaheen et al., 2016). TNC legislation does not currently address differing regulations and financial advantages of TNCs, despite TNCs providing similar for-hire pick-up and drop-off services to taxis, limousines, and liveries (Daus, 2016).	• Level the playing field for all for-hire services with a combination of regulatory devolution that reduces regulations for taxis, limousines, and liveries and increasing regulation for TNCs, resulting in similar regulation for all services.
		• Automated vehicles may result in a decreased need of regulatory and enforcement staff, such as police officers, because vehicles need to be regulated rather than drivers (James, 2018; Greco, 2017).	• Establish an agency roadmap for transitioning regulations to address emerging issues raised by vehicle automation (e.g., vehicle inspections, consumer protection, insurance). • Participate in stakeholder meetings convened by organizations, such as the Department of Labor, on potential workforce changes to gain a better understanding of potential negative impacts and how to mitigate them.

Stakeholders		Issues	Potential Actions
Service Providers	Freight Companies	• Widespread deployment of self-driving trucks could eliminate the need for some jobs and create downward wage pressure for other jobs (Kennedy, 2017).	• Respond to potential impacts from vehicle automation by retraining existing staff (GAO, 2019).
Service Providers	MOD Service Providers	• Classifying workers as independent contractors or employees (e.g., California's Assembly Bill 5) has led to regulatory challenges, such as specifying required benefits and legal protections (International Municipal Lawyers Association, 2018; Bernhardt and Thomason; 2017; Gurley, 2019). • Public sector partners, such as public transit agencies, may be resistant to adopting new technologies (e.g., low-speed shuttles, automated buses) due to concerns, such as high capital costs (Rea et al., 2017).	• MOD providers can classify their laborers as employees and abide by relevant state and local labor laws to clarify employee requirements and benefits. • Mobility service providers can engage with public transit agencies and public transportation labor unions to develop a framework for fleet adoption and address potential concerns with automation. • Operate automated services in areas where there are no existing transportation services (e.g., traditional bus) to avoid labor conflicts.
Service Providers	Public Transit Agencies	• Workforce requirements may change due to the nature of MOD, necessitating the need for new or different roles, such as data scientists (Wells et al., 2019). • Mobility service providers may need liability insurance for subcontractors (e.g., workers who collect and recharge parked shared micromobility devices) (Cregger et al., 2018). • Public agencies may have special workforce requirements (e.g., background checks, alcohol and drug testing) if they received federal funding (National Academies of Sciences, Engineering, and Medicine, 2019; Federal Transit Administration, 2016).	• Coordinate with public transportation worker organizations on retraining staff members to gain skills to manage emerging technologies. • Include liability insurance clauses for subcontractors in partnership contracts. For example, liability insurance could extend to rechargers ("juicers") or equipment maintenance for shared micromobility companies.

Stakeholders		Issues	Potential Actions
Service Providers (cont.)	Public Transit Agencies (cont.)	• Workforce roles may change as automated fleets develop, and these changes may include human assistants for automated paratransit or new, highly skilled staff for inspecting and maintaining automated transit buses at all levels of automation (Greco, 2019; Federal Transit Law, 2018).	• Recognize emerging workforce needs and requirements, identify new future career paths, and conduct succession planning in this new, high-technology environment. • Public transit agencies can work with FTA, industry associations, and private sector consultants to identify core training needs; academic institutions may be able to assist in implementing training.
		• MOD services may create competitive pressures on wages and benefits for public transit agency staff (Klim et al., 2016).	• Continually engage with transit agencies and local regulatory authorities to identify strategies to manage competitive pressures, such as regulatory devolution for transit agencies.
Workers and Representation	Public Transportation Unions	• Automated fleet vehicles may result in the need for a smaller workforce or necessitate workforce development and retraining (Shaheen and Cohen, 2018c).	• Coordinate with transit agencies on retraining staff to gain automation-related skills and providing advance notice on the adoption of automated fleet vehicles.
	Taxi Unions	• Independent contractors working for TNCs may create downward pressures on taxi driver wages and benefits (Shaheen et al., 2018).	• Implement caps on TNC fleet size and the establishment of a minimum wage (e.g., legislation advocated for by the New York City Taxi and Limousine Commission) (Burns; 2018).

Independent Contractor Legislation

In September 2019, the California legislature passed Assembly Bill 5 (AB 5) to reclassify many California sharing economy workers as employees and add employee protections and benefits for these job classifications in state labor law.

As of August 2019, seven states (Arizona, Florida, Indiana, Iowa, Kentucky, Tennessee, and Utah) have passed laws exempting sharing economy workers from being classified as employees. Several sharing economy companies are lobbying for a federal bill that would supersede independent contractor re-classification, such as the California legislation (Pinto et al., 2019).

Key Takeaways

- MOD is impacting transportation labor in a variety of ways, such as creating demand for new jobs while disrupting others.
- Key stakeholders in transportation labor include regulators, service providers, represented workers, and non-represented workers.
- The potential negative impacts of MOD on labor could be addressed in a variety of ways, such as labor regulation (e.g., establishing a minimum wage) and workforce development.

MOD and Transportation Equity

The demographics of shared mobility users have historically differed from the general population. Many studies of shared mobility have documented user demographics that typically reflect younger ages, higher levels of educational attainment, higher incomes, and less diversity than the general population. Older adults, low-income individuals, rural communities, and minority households have historically been less likely to use shared mobility. Additionally, access to the Internet, smartphones, and banking services—a prerequisite for many services—tends to be lower among many of these groups (Shaheen et al., 2017).

Digital Accessibility

With the emergence of app-based transportation services, digital and physical accessibility are both important for accomplishing a complete trip. For example, as part of the USDOT's MOD Sandbox program, Valley Metro (a public transportation agency in Maricopa County, Arizona) has developed the Pass2Go app, an accessible mobile ticketing and multimodal trip planning interface that links to app-based transportation options. Valley Metro has consulted with digital accessibility specialists and stakeholder organizations to ensure that Pass2Go is accessible by people with a variety of disabilities.

The MOD ecosystem offers a variety of transportation modes and services that may enhance mobility. However, MOD may present challenges for travelers' ability to complete a trip due to a variety of gaps that may inhibit digital or physical accessibility (Colby and Bell, 2016). A complete trip is one in which an individual is able to plan and execute a trip from origin to destination without gaps in the travel chain. If one link is not accessible, then access to a subsequent link is unattainable and the trip cannot be completed. Figure 15 illustrates the links that create the complete trip.

Figure 15. The Complete Trip

Source: Shaheen et al., 2017

In addition to physical and digital accessibility, social equity and environmental justice are important considerations for MOD. MOD can enhance access and opportunities for underserved communities (Canep et al., 2019; Carley et al., 2019). However, MOD may also have adverse equity and environmental justice impacts, particularly if a community bears a disproportionate share of the benefits or adverse impacts of MOD (e.g., lack of services in low-income or minority communities, lack of ADA accessible services, etc.) (Downey et al., 2008). While communities continue to overcome many barriers and improve access to MOD, some equity challenges may still exist (Shaheen et al., 2017). This section provides a framework for identifying MOD equity challenges and practices to help overcome these challenges and enhance equitable access to MOD.

The Spatial, Temporal, Economic, Physiological, and Social (STEPS) to Transportation Equity Framework

The STEPS framework can be used to address environmental justice[6] challenges. To understand potential equity challenges impacting users, stakeholders can apply the STEPS framework (Shaheen et al., 2017). STEPS stands for Spatial – Temporal – Economic – Physiological – Social. These barriers are defined as:

Spatial barriers create physical gaps in the transportation network, such as the lack of service availability in a particular neighborhood, excessively long distances between destinations, and lack of public transit within walking distance.

Temporal barriers create gaps in the transportation network during particular travel times, such as the inability to complete off-peak or late night trips due to lack of services (e.g., very long public transportation headways during the late night hours).

Economic barriers include financial challenges, such as high direct costs (e.g., fares, tolls), indirect costs (e.g., smartphone ownership), and structural barriers (e.g., banking access) that may preclude users from using MOD.

Physiological barriers include physical and cognitive limitations that make using standard transportation modes difficult or impossible for certain individuals (e.g., people with disabilities, older adults, etc.).

Social barriers include social, cultural, safety, and language challenges that may inhibit a potential rider's comfort with using transportation modes and services (e.g., poorly targeted marketing, lack of multi-language information, neighborhood crime).

More information on the STEPS framework can be found in Travel Behavior: Shared Mobility and Transportation Equity.

[6] The USDOT defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of transportation services, laws, regulations, and policies. Fair treatment means that no group of people should have disproportionate access to a service as a result of government and commercial transportation operations or policies. Meaningful involvement means that: 1) people have an opportunity to participate in decisions about activities that may affect them, 2) the public's contribution can influence regulatory agencies' decisions, 3) people's concerns will be considered in the decision-making process, and 4) policymakers will seek out and facilitate the involvement of people specifically affected. For more information on the USDOT's environmental justice policy, please see Transportation Policy - Environmental Justice.

Increasing Shared Micromobility Accessibility

Increasingly, there is growing awareness of MOD accessibility needs for people with a range of abilities. A few studies have examined accessibility challenges and potential strategies for shared micromobility. MacArthur et al. (forthcoming) found that for people with disabilities and older adults, standard bicycles used in bikesharing programs are generally physically inaccessible for users with special mobility needs. These users face challenges due to users' lack of strength, balance, pre-existing health conditions, or inability to operate the bicycle. The inclusion of adaptive bikes, such as electric bikes or tricycles, in bikesharing fleets may allow more people to use these services. However, there are barriers to increasing the accessibility of shared micromobility due to challenges with parking adaptive bicycles and difficulties dispersing adaptive services equally. A key challenge in increasing bikesharing accessibility is addressing a variety of user needs in a standardized fleet of bicycles. Adaptive cycles may include a variety of features and cycle styles such as handcycles, three-and four-wheeled cycles, tandem cycles, combination hand and foot cycles, and hand and foot cycles for children and smaller adults.

Alta Planning, a private planning and design firm, authored *Accessible Scooter Share*, a document that discusses a variety of features that could be included in scooter sharing services to increase their usability by people with a range of abilities (Crowther, n.d.). For example, adaptive scooters could include cargo storage for assistive devices (e.g., walkers), thicker wheels and wider platforms for balance, tandem units to be used by assistants, and stable seating (Crowther, n.d.). Additionally, the user interface of shared micromobility apps should be accessible by people with cognitive, visual, or auditory impairments. More research is needed to expand the accessibility of shared micromobility and other MOD services for older adults and people with disabilities.

Figure 16. Adaptive Scooter

Source: Razor, 2019.

Figure 17. Adaptive Cycle

Source: Bay Area Outreach and Recreation Program, 2019

Common Equity Challenges and Potential Actions

The STEPS framework can be used to identify a variety of equity challenges for users accessing MOD. Four common equity challenges include:

- **Access by Un-or Under-Banked Households** – MOD services may require a credit card, debit card, or credit hold to access services, which may not be feasible for households that do not have access to financial institutions.
- **Digital Divide –** MOD services may require a smartphone or Internet access. These requirements may present themselves as a barrier for low-income or rural households.
- **Accessibility –** Digital platforms (e.g., smartphone apps) and mobility services (e.g., vehicles, bicycles, scooters, etc.) may not be accessible to people with physical, cognitive, auditory, visual, or other disabilities.
- **Affordability –** MOD may be more expensive compared to traditional transportation modes (e.g., cycling, walking, public transportation) that could limit financial accessibility to these services.

Table 21 provides examples of additional equity challenges and use cases that MOD may be able to help overcome.

Table 21. Equity and MOD Case Studies

		Potential Opportunities	Example
Spatial	**Low-Density Service**	MOD can provide service coverage in low-density areas	*Via – Arlington, TX* The City of Arlington is supplementing its existing bus system with a partnership with the microtransit company, Via, to provide on-demand rides in its low-density service area. Customers can request a ride through the Via app or through a customer service telephone number and rides cost a flat fee of $3, paid through a credit card or prepaid card. Via's fleet also includes wheelchair accessible vehicles to allow wheelchair users access to the program (Clabaugh, 2004; Clabaugh, 2005).
Temporal	**Off-Peak Service**	MOD can provide transportation to supplement or replace existing fixed-route services during off-peak times	*Transportation Disadvantaged (TD) and Late Shift Programs -- Pinellas County, FL* Pinellas Suncoast Transit Authority (PSTA) partners with TNCs, taxis, and paratransit providers to offer subsidized, on-demand rides during off-peak hours (i.e., 10 PM – 6 AM) for individuals living in Pinellas County, with an income less than 150% of the poverty guideline, and who cannot otherwise complete life-sustaining trips (Forward Pinellas and PSTA, 2017). TD bus passes cost $11 a month and TD clients can pay an additional $9 a month for PTSA's Late Shift program which provides riders with 25 on-demand rides a month from 10 PM to 6 AM.
Economic	**Low-Income Affordability**	MOD can offer affordable transportation options for low-income communities	*BlueLA – Los Angeles, CA* In 2015, the California Air Resources Board sponsored the BlueLA pilot program through the California Climate Investments initiative to provide all-electric carsharing services to Los Angeles residents. The California Public Utilities Commission's cap-and-trade fund provides $1.7 million for the BlueLA program and the LA Department of Water and Power gives an additional $400,000. BlueLA offers 100 vehicles, 200 charging stations, and charges $0.20 per minute for standard members and $0.15 per minute for low-income members to use. Users can qualify as low-income members through a proof of income below a certain threshold or proof of participation in a public assistance program (BlueLA; n.d.).
Physiological	**ADA Accessibility**	Operator permit programs may be used to encourage or require mobility providers to allocate a percentage of their fleet to accessible vehicles/equipment	*Seattle Department of Transportation (SDOT)* – Seattle, WA SDOT uses its dockless bikesharing permitting system to incentivize operators to encourage the use of adaptive cycles. SDOT uses $50,000 of its permitting fees to partner with existing providers to develop and promote opportunities for recreational cycling and offer additional adaptive cycle services (e.g., fittings, storage) for adaptive cycle users. SDOT also offers the opportunity for dockless bikesharing operators to deploy an additional 1,000 bicycles in their fleet if they deploy adaptive cycles.
Social	**Outreach**	Outreach in a variety of languages may be able to maximize community and stakeholder feedback	*Citi Bike Bikesharing Program – New York, NY* Prior to the implementation of the Citi Bike bikesharing Program, the NYCDOT conducted 159 public meetings, presentations, and demonstrations in three languages as well as virtual outreach methods that yielded 10,000 station suggestions and 55,000 notices of support for proposed stations (New York City DOT, 2013). This process culminated in 2,881 community suggested bikesharing station locations for city consideration (New York City DOT, 2013). The extensive outreach resulted in 74% of New Yorkers supporting the bikesharing program.

Legislation and Regulation Supporting MOD Equity

Legislation and regulation requiring minimum service standards for MOD can help ensure that users and communities with a variety of needs have access to the potential benefits of on-demand mobility. Some existing legislative examples that may be applicable to promoting equitable access include:

- **Americans with Disabilities Act of 1990 (ADA)**: The ADA prohibits discrimination against people with disabilities on the basis of their disability and requires public agencies to provide equitable service to people with disabilities if they are not able to use existing services.
    - **The Rehabilitation Act of 1998 - Section 508**: This section of the ADA requires that federal agencies must ensure all electronic and information technology, including websites and mobile apps, are accessible by people with disabilities. Accessibility features of technology may include use of phones' haptic (i.e., touch-based responses, such as vibrations) capabilities or ability of text to be processed by screen readers.
- **Civil Restoration Act of 1987**: This law prohibits discrimination within an organization or agency if the organization or agency receives federal funding.
- **The Rehabilitation Act of 1973:** This law prohibits programs, agencies, or activities that receive federal funding from discriminating against people with disabilities.
- **Title VI of the Civil Rights Act of 1964**: This law prohibits discrimination based on race, color, and/or national origin in any program or activity that receives federal funding. This title prohibits discrimination in federally funded programs and requires equivalent service provision for individuals who are unable to access certain services, such as banking and smartphones.

Regulation can also play a key role ensuring equal access to MOD. A few key pieces of landmark federal regulation that may be applicable to MOD include:

- **Title 49 CFR Part 21**: This regulation implements provisions of Title VI for any program or activity receiving federal funding from the USDOT.
- **Title 49 CFR 37.105**: This regulation implements equivalent service provisions with respect to schedules/headways; response time; fares; geographic area of service; hours and days of service; availability of information; reservations capability; constraints on capacity and service availability; and restrictions based on trip purpose.

The federal government can also ensure equity through other means, such as the U.S. Access Board, executive orders, and international efforts to increase equity. Some examples include:

- **U.S. Access Board:** The U.S. Access Board is an independent federal agency that promotes equality for people with disabilities through leadership in accessible design and the development of accessibility guidelines and standards. Created in 1973 to ensure access to federally funded facilities, the U.S. Access Board is a leading source of information on accessible design. The Board develops and maintains design criteria for the built environment, transit vehicles, telecommunications equipment, medical diagnostic equipment, and information technology. The Board also provides technical assistance and training on accessible design and continues to enforce accessibility standards that cover federally funded facilities.

- **Executive Order (EO) 12898 – Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations:** This Executive Order requires federal agencies to prioritize environmental justice as a way to increase transportation equity for minority and low-income communities.

- **Web Content Accessibility Guidelines (WCAG) 2.0:** These guidelines are published by the Web Accessibility Initiative of the World Wide Web Consortium, an international non-governmental organization that guides international Internet standards. The WCAG informs agencies of what accessibility elements should be considered in website and app developments including the ability to understand error alerts, auditory accessibility, and visual understanding.

Examples of State and Local Legislation

At the state and local levels of government, regulation and legislation can also be important for ensuring equitable access to MOD. For example, California and the City of Sacramento have implemented the following laws and ordinances:

- **California's Disabled Persons Act:** This law prohibits discrimination against people with disabilities in transportation by requiring equal access to all modes of transportation available to the general public.

- **California's Unruh Civil Rights Act:** This law prohibits discrimination against protected classes and guarantees the right to full and equal accommodations, advantages, facilities, privileges, or services in all business establishments.

- **Sacramento's City Code Regulating Shared-Rideable Business and Operations:** In April 2019, the City of Sacramento amended sections of its city code regarding "shared-rideables" (i.e., shared dockless scooters or bikesharing bicycles). These amendments require the distribution of 20% of fleets into areas classified as opportunity areas, the development of equity plans, and the leveraging of fines for shared devices that block or restrict walkway or ramp access.

Communities, such as Chicago, San Francisco, and Seattle, are attempting to address accessibility challenges by leveraging fees on shared mobility, such as TNC accessibility fees. These fees contribute to accessibility funds that the communities can use to improve their transportation networks.

Organizations such as the American Federation of Labor and Congress of Industrial Organizations (AFL-CIO) and the Canadian Labour Congress (CLC) have also supported equity in transportation by reviewing efforts of transit agencies and their partnerships to provide accessible demand response services for people with disabilities (American Federation of Labor and Congress of Industrial Organizations and the Canadian Labour Congress, 2016).

Key Takeaways

- MOD may be able to enhance accessibility for underserved communities, but it may also have adverse impacts if a particular population or community bears a disproportionate share of the benefits or adverse impacts of MOD.
- Physical and digital accessibility are key considerations for some vulnerable populations to accomplish a complete trip.
- The STEPS Framework (Spatial, Temporal, Economic, Psychological, and Social) can be used by stakeholders to identify, prevent, and mitigate potential equity barriers to accessing MOD.
- MOD stakeholders may be able to address common STEPS barriers by:
    - Requiring or incentivizing mobility service providers to serve underserved communities.
    - Facilitating off-peak partnerships to provide late-night transportation service using shared mobility.
    - Subsidizing access to shared mobility for qualifying low-income users and offering alternative access modes (e.g., telephone concierge service, text messaging access, etc.) that do not require a smartphone or high-speed data access.
    - Expanding access for people with disabilities and older adults through wheelchair accessible vehicles (WAVs), adaptive devices, personal assistants, and assistive technologies.
    - Preventing the blocking of access to pedestrians and people with disabilities (e.g., sidewalks, curbs, and ramps) by shared mobility services (e.g., bikes, scooters, TNCs, etc.).
    - Conducting education and outreach to an array of potential users, such as low-income, minority, and immigrant households, for example.
- The public sector can play an important role ensuring equitable access to MOD through regulation and legislation.

CHAPTER 6: Innovative and Emerging Mobility Futures

The transportation landscape is changing and assessing how best to accommodate shared, automated, and aerial modes. Developments in vehicle automation and changes to existing business models are evolving to include automated vehicles (AVs) and shared automated vehicles (SAVs). Similar technological developments in aircraft and the aviation industry are supporting urban and rural air mobility pilots. The impacts of these technological developments can also be seen in emerging last-mile delivery options, which feature modes such as robots, automated delivery vehicles (ADVs), and unmanned aircraft systems (i.e., drones). Other innovations, such as 3D printing (i.e., building a three-dimensional object from a computer-aided design) could have many applications for MOD, such as reducing the cost of creating devices and vehicles and enabling consumers to print adaptive devices to enhance the accessibility of MOD.

This chapter discusses innovative and emerging technologies that could have a transformative effect on communities in the future. The first section discusses the potential impacts of shared automated vehicles. The next section introduces key concepts and planning considerations for urban air mobility. The final section discuses last-mile delivery strategies, including unmanned aerial vehicles and automated delivery robots and vehicles.

Shared Automated Vehicles (SAVs)

The convergence of shared mobility, vehicle automation, and electric-drive technology has the potential to transform the way people travel and access goods. Vehicle automation and electrification coupled with pooling could result in shared automated vehicles (SAVs) that offer for-hire services that could be less expensive on a per mile basis than privately owned vehicles. SAVs are AVs that are shared among multiple users and can be summoned on-demand, similar to taxis and TNCs, or can operate a fixed-route service similar to public transportation (Shaheen and Cohen, 2018a). SAVs could have a disruptive impact on traveler and consumer behavior (Shaheen and Cohen, 2018c). This section summarizes various levels of automation, development trends for AVs and SAVs, business models, potential impacts, case studies, and future trends.

Levels of Automation

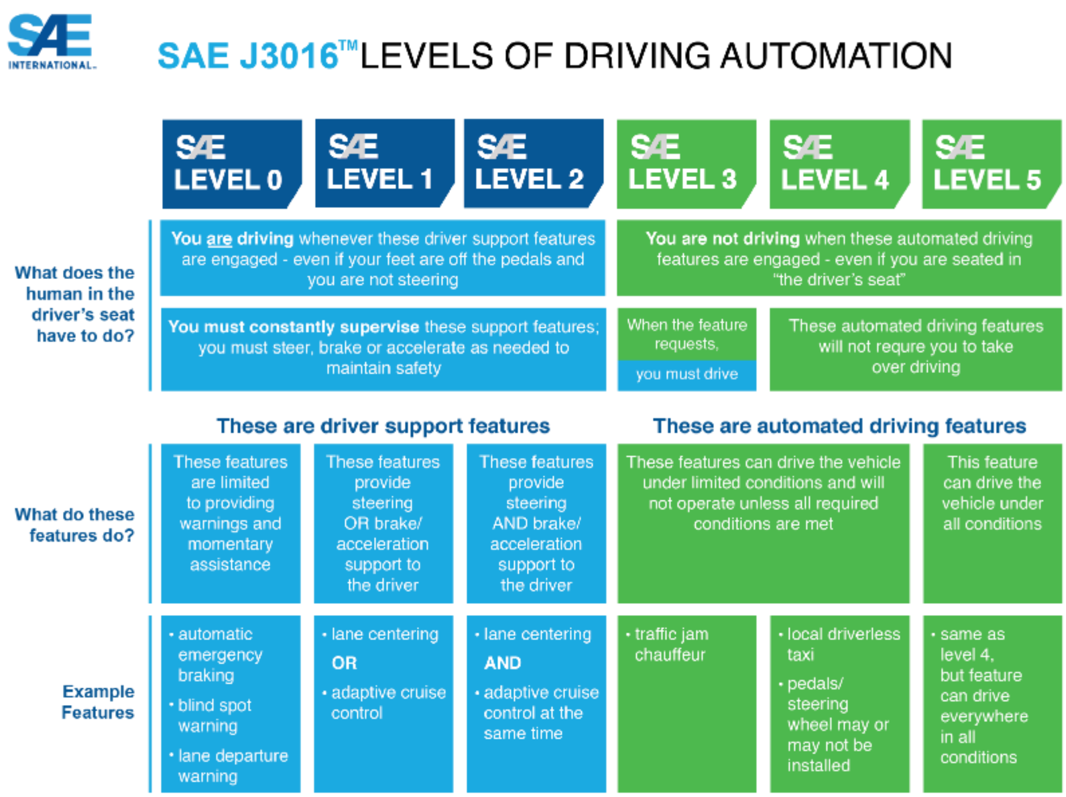
SAE International, a global mobility standards organization, has established five levels of vehicle automation. These levels of automation define the level of control needed from the human operator or provided by the vehicle. SAE's levels of automation are:

- **Level 0:** Vehicles are not automated and drivers perform all of the tasks.
- **Level 1:** Vehicles automate only one primary control function (e.g., self-parking or adaptive cruise control).

- **Level 2**: Vehicles with automated systems that have full control of specific vehicle functions such as accelerating, braking, and steering, but drivers must still monitor driving and be prepared to immediately resume control at any time.
- **Level 3:** Vehicles allow drivers to engage in non-driving tasks for a limited time. Vehicles will handle situations requiring an immediate response; however, drivers must still be prepared to intervene within a limited amount of time when prompted to do so.
- **Level 4:** A human operator does not need to control vehicles as long as the vehicles are operating in the specific conditions in which it was intended to function.
- **Level 5**: Vehicles are capable of driving in all environments without human control.

Figure 18 summarizes these levels of automation.

Figure 18. SAE Levels of Automation



Source: SAE International, 2019

Automated Vehicle (AV) Business Models

Business models could likely impact the evolution and deployment of AVs and SAVs. AVs and SAVs could eventually evolve from present day ownership and business models similar to how shared mobility and micromobility services are currently deployed (Stocker and Shaheen, 2017). Potential ownership and business models could include:

- **Business-to-Consumer** (B2C) – A company owns or leases a fleet of SAVs that are accessible to riders via a membership or per-use fee.
- **Peer-to-Peer** (P2P) – A company provides the resources to facilitate the short-term use of a vehicle between a host (the owner) and a guest (the lessee).
- **Fractional Ownership –** Multiple parties share the cost of purchasing and maintaining an AV in exchange for personal use and access.
- **Private Ownership** – An owner buys or leases an AV for personal use, similar to private vehicle ownership.
- **Publicly Owned and/or Operated** – A public agency owns and operates AVs similar to public transportation. This could include both large vehicles (e.g., buses) and smaller vehicles (e.g., shuttles and SAVs).

Increasing levels of automation and potential ownership and business models are anticipated to impact how and where AVs and SAVs are deployed. Table 22 details anticipated AV and SAV levels of automation from Level 3 to Level 5 automation, operational design domains, areas of deployment, and potential impacts. An operational design domain (ODD) is the specific conditions an automated system is designed to function in, including limitations, such as geography, traffic, speed, and roadway typology (Stocker et al., Forthcoming).

Table 22. AV and SAV Deployment Framework

Model	Phase 1: Present day	Phase 2: Specific-ODD Automation	Phase 3: Citywide-ODD Level 4	Phase 4: Proliferation of Level 4+
Operational Design Domain (ODD)	Highway and defined areas	Highway, defined areas, and some city streets	Highway, major cities, and metropolitan areas	Highway, many cities and metropolitan areas
In-Vehicle Supervision Required	Yes	In most situations	No	No
Privately Owned AVs	Small penetration of Level 2 automation on select new vehicle models (e.g., Tesla Autopilot, Nissan ProPILOT)	Level 2 and 3 features continue to roll out slowly in new vehicle models. May see greater penetration of personally owned AVs used for highway driving.	Some private ownership of Level 4 vehicles. AV penetration will depend on upfront and operating costs of automated technology. However, AV retrofit kits could increase private AV ownership rates.	Decreasing cost of AV technology may make ownership possible for a greater portion of the population. Private AV ownership may be segmented by land-use context due to cost differences (e.g., AV ownership in suburban/rural areas, SAV services in dense cities).
Shared Fleet SAVs	Small but growing number of low-speed SAV pilots and testing (e.g., EasyMile, May Mobility) and SAV pilots and testing with conventional vehicles (e.g., Waymo, GM/Cruise)	Additional SAV pilots emerge, most likely at low speeds and serving specific use cases and geographical areas (first- and last-mile to transit services, office parks, downtown circulators, etc.).	Removal of human operator in vehicle and introduction of SAV services in major cities and metropolitan areas with high rates of travel demand. Potential for vehicle ownership reductions, modal shifts away from public transit and personal vehicle driving, and possible changes in walking and cycling.	Shared fleet SAV services gain more ridership, expand to more cities and into some suburban areas. Possibility for even greater reduction in privately owned vehicle rates but also in public transit ridership.

Source: Stocker et al., Forthcoming

Potential Impacts of AVs and SAVs

Vehicle automation could result in fundamental changes by altering the built environment and land use, household transportation costs, commute patterns, and mode choice. The adoption of AVs and SAVs may be impacted by the public's perceptions towards automation and the potential safety impacts (Automated Vehicles for Safety, 2017). Public agencies can pursue a variety of policies to prevent and mitigate potential adverse impacts of vehicle automation and maximize the likelihood of sustainable outcomes (Autonomous Vehicles State Bill Tracking Database, 2019). Potential impacts that public agencies may have to address include:

- **Environment and Land Use Impacts –** Reduced vehicle ownership due to SAVs could result in more compact urban centers and shorter commutes due to the repurposing of parking for infill development. Sharing vehicles or commute trips amongst multiple individuals would require people to live relatively close to one another and their respective jobs. However, the growth of telecommuting and AVs could also make longer commutes more practical, which could shift consumer preferences in favor of living in less dense built environments (e.g., suburbs, exurbs, and edge cities).
- **Labor and Economic Impacts –** The impacts of vehicle automation on public transit, goods delivery, and other sectors of the transportation workforce are uncertain. Automation reduces costs associated with passenger and goods transportation and creates new job opportunities associated with research and development, vehicular maintenance, and transportation security, supporting economic growth. However, vehicle automation could result in job losses in transportation operations and logistics.
- **Social Equity Impacts –** The impacts of vehicle automation on equity and access are uncertain. Vehicle automation could reduce transportation costs for low-income households and create new opportunities for healthcare and job access. However, if vehicle automation lacks services for people with disabilities, or requires a credit card or a smartphone to use services, some travelers may not be able to access mobility services.

Preparing Labor for the Impacts of Automation

The USDOT is working with other federal agencies (e.g., Equal Employment Opportunity Commission [EEOC], Economic Development Agency [EDA]) on a comprehensive analysis of the employment and workforce impacts of automated vehicles. The USDOT has also begun reaching out to stakeholders and sponsoring research on workforce issues affecting their respective modes of transportation.

Entities involved in developing and deploying automation technologies may want to consider how to assess potential workforce effects, future needs for new skills and capabilities, and how the workforce will transition into new roles over time. Identifying potential impacts and training needs now will help prepare the American workforce for the appropriate skills to support innovative transportation technologies (U.S. Department of Transportation, 2019).

- **Travel Behavior Impacts –** The impacts of vehicle automation on travel behavior are uncertain. Vehicle automation could result in more or less congestion depending on how vehicles are used (e.g., traveling without passengers [deadheading], single passenger use, or pooled use).

- **Public Transit Ridership –** SAVs could lead to a decreased need for parking, resulting in the repurposing of parking for infill development and increased density, which would support public transit ridership. AVs and SAVs could also reduce transit operating costs, which could potentially pass savings on to riders as reduced fares and increase the appeal and competitiveness of public transit. Alternatively, AVs and SAVs could reduce transit ridership due to telecommuting and AVs supporting longer commutes and shifting consumer preferences towards suburban and exurban living (Shaheen and Cohen, 2018c). This change in preferences could result in fewer workers commuting with public transportation. More research is needed to conclusively determine the impacts of automated vehicles on transit ridership.

SAVs present a number of potential opportunities and challenges. These potential outcomes are organized in a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis in Figure 19. A SWOT analysis divides potential impacts between external and internal components, and positive and negative impacts.

Figure 19. SWOT Analysis of Potential AV and SAV Outcomes

Internal

	Strengths	Weaknesses	
Positive	○ Data that is both shared and monitored in order to protect the consumer. Data is aggregated and/or anonymized to allow public sources share data freely and accurately, with no privacy risks to consumers through aggregation and/or anonymization ○ Ubiquitous adoption of sophisticated information management systems and short-range communication to increase vehicle safety as well as traffic and route efficiencies ○ Sharing of AVs to create more efficient vehicle use and mitigate negative environmental impacts	○ Data about vehicle operations are not shared for public benefits ○ Lack of oversight of private companies' use and sharing of data about customer ○ Limited adoption of standardized information formats and short-range vehicle communication protocols, or widespread adoption of non-standardized information formats and short-range vehicle communication protocols	Negative
	Opportunities	**Threats**	
	○ Dramatic urban redesign and land-use shifts to promote multimodal and efficient transportation options while increasing accessibility and mobility ○ Compounding economics to support penetration of Zero Emissions Vehicles (ZEVs, electric and hydrogen-powered vehicles) and investment in alternative fuel infrastructure	○ Urban redesign solely around vehicle-only travel ○ Significantly higher VMT from increased short-range point-to-point travel as well as displacement of other high-density regional travel modes ○ System-wide travel patterns that favor gas-powered internal combustion engines and diminish investment returns for ZEVs ○ Lack of coordination regulation may lead to disjointed and confusing regulatory environment	

External

Source: Shaheen, Cohen, Broader, Davis, and Farrar, 2019.

The potential weakness and threats identified in the SWOT analysis can be addressed through a variety of policies and actions. Table 23 provides a brief overview of potential policies for a driverless vehicle future, organized by impact area.

Table 23. Potential SAV Policies

Impact Area	Policy	Description
Environment and Land Use	**Curbspace Optimization**	AVs may be able to provide data that can support dynamic curbspace management and related policies, such as curbspace pricing.
	Expand EV Adoption	Public agencies may consider requiring zero-emission AVs and funding electric vehicle infrastructure to reduce the environmental impacts of vehicle automation.
	Infill Development and Parking Replacement	Vehicle automation could result in a reduction in parking demand. Zoning and development policies (e.g., reducing minimum parking requirements, streamlining permits for mixed-use developments, etc.) could allow for the conversion of parking to other uses and could support infill development and affordable housing.
	Urban Growth Boundary	Land use policies, such as urban growth boundaries and open-space preservation, could help prevent suburban and exurban sprawl and encourage infill development within existing urban areas.
	Occupancy Requirements, Pricing, and Pooling Policies	In an AV future, minimum occupancy requirements, road pricing, and policies that encourage shared rides could be important to prevent or mitigate potential increases in VMT.
Labor and Economy	**Workforce Development Programs**	Public transit agencies could provide employees with advanced notice of any planned deployment of AV technologies and the potential impacts these technologies could have on the current workforce. Local and state agencies could implement workforce development programs that include job training and job placement services for former drivers and other workers adversely impacted by vehicle automation.
Travel Behavior	**Multimodal SAV Planning**	Policies that integrate with public transportation (e.g., mobility hubs, integrated fare payment) and encourage first- and last-mile connections could help ensure a complementary relationship between SAVs and public transportation.
	Pricing	Pricing policies may help prevent and mitigate induced demand associated with automated vehicles and encourage higher occupancies and travel at off-peak times.
Social Equity	**Comprehensive Equity Policy**	Equity policies could be developed to address access to driverless vehicle services for people with disabilities, low-income and underbanked communities, and people without access to a smartphone or high-speed data. Complying with an equity policy could be a precondition for vehicle registration, permitting, or access to the public rights-of-way.
	Low-Income Programs	Policies requiring programs for low-income households, such as subsidies and cash payment options, could reduce household transportation costs and enhance mobility access for low-income households.

Sources: Electric Vehicles, n.d.

Vehicle Automation and Rights-of-Way Management

In addition to the potential impacts of AVs on the built environment and land use, vehicle automation may also require changes in rights-of-way and curbspace management. These areas may be adapted to accommodate MOD, AVs, and SAVs, as well as multimodal integration. Vehicle automation may require curbspace to be adapted for AVs and SAVs, such as dedicating curbspace for different modal uses to address safety concerns, establishing flex zones (i.e., spaces with multifunctional purpose depending on the time of the day including loading zones for people and goods during the day, parking at night), and increasing the number and size of passenger and delivery loading zones. Additionally, lane distribution on roadways could change with the deployment of AVs/SAVs. For example, high-occupancy vehicle (HOV) lanes may need to become SAV-only lanes to mitigate congestion and/or decrease potential conflicts with human-driven vehicles. Examples of potential lane classifications are summarized in Table 24.

Table 24: Potential Lane Classifications for AVs

Occupancy	*Characteristics*	*Description*
Zero	No driver or passengers in the vehicle	Fully automated vehicle driving to/from parked location
Single	One passenger in the vehicle	One passenger riding in fully autonomous vehicle
	One driver in vehicle	One driver operating non-autonomous vehicle
High Occupancy	Multiple passengers (2+)	At least two passengers riding in a fully autonomous vehicle, may or may not share destination and origin
	Multiple passengers (2+)	One driver and one or more passengers in a non-autonomous vehicle
	Bus only	Lane reserved exclusively for use by public transit buses

It should be noted, however, reclassifying vehicular lanes is not limited to occupancy-based characteristics. Vehicular lanes may be reclassified in a variety of ways, such as by operational characteristics (e.g., human-driven vs. automated). Lane classifications could also be dynamic and change based on time of day and/or roadway demand.

Case Studies

EasyMile - San Ramon, CA

Figure 20. EasyMile

Source: GoMentum, 2018

The Contra Costa Transportation Authority (CCTA) and GoMentum, a testing site for connected AVs in Concord, California, have been developing an autonomated shuttle program, EasyMile. In January 2018, for the first time in the state's history, the California DMV granted permission for CCTA and GoMentum to test EasyMile on public roads. In March 2018, CCTA and GoMentum announced their plan to test EasyMile at Bishop Ranch and the surrounding community. For the first year, EasyMile will be tested by trained testers, but ridership will eventually expand to employees of the Bishop Ranch area. CCTA and GoMentum believe that automated shuttle programs, like EasyMile, could offer a safe and accessible transportation service that can overcome first-and last-mile challenges and potentially decrease congestion, reduce GHG emissions, and provide affordable access to transportation hubs (Wills, 2018).

Ultimate Urban Circulator (U2C) – Jacksonville, FL

Figure 21. Ultimate Urban Corridor

Source: Bizjournals, 2018

Jacksonville, Florida currently has a monorail system, the Skyway, that covers 2.5 miles with eight stations in Downtown Jacksonville. According to community surveys, the Skyway system fails to reach some of Jacksonville's popular neighborhoods and destinations. To overcome this challenge, the Jacksonville Transportation Authority is working on a multi-phased program, the Ultimate Urban Connector (U2C), to convert the Skyway into an automated vehicle network that connects more areas than the existing Skyway system. As the Skyway is transitioned into an AV network, developers are working on identifying locations for bridges and inner loops to expand the service area and increase connectivity and are researching options to expand service hours and days. The goals of the U2C are to link neighborhoods more efficiently and increase access to employment, residential, retail, medical and educational centers (Jacksonville Transportation Authority, 2019).

Waymo – Phoenix, AZ

Source: Business Insider, 2018

In December 2018, Alphabet's self-driving project, Waymo, launched its first commercial SAV service (Korosec, 2018). A little over a year prior, in April 2017, Waymo began testing autonomously driven vehicles with a test group of people in its "Early Riders" program. Early Riders was a group of 400 people who applied to be part of the program and used Waymo's autonomously driven vehicles for free, in exchange for providing feedback on Waymo through surveys, panels, interviews, and ride-alongs with Waymo researchers (Hawkins, 2018c). The feedback from the Early Riders informed the launch of Waymo's commercial SAV service (Hyatt, 2018). Waymo's service will only be available in the Chandler, Mesa, Tempe, and Gilbert suburbs of Phoenix, a service area of approximately 100 square miles (Hawkins, 2018c). Rides are dispatched through an app with a similar interface and pricing to that of TNCs.

Accessible Transportation Technologies Research Initiative (ATTRI) – USDOT

ATTRI focuses on emerging research, prototyping, and integrated demonstrations with the goal of enabling people to travel independently and conveniently, regardless of their individual abilities. ATTRI research focuses on removing barriers to transportation for people with disabilities, veterans with disabilities, and older adults, with particular attention to those with mobility, cognitive, vision, and auditory disabilities. By leveraging principles of universal design and inclusive information and communication technology, these efforts are targeting strategies that could be transformative for independent mobility.

ATTRI applications in development include wayfinding and navigation, pre-trip concierge and virtualization, safe intersection crossing, and robotics and automation. Automated vehicles and robotics are expected to improve mobility for those unable or unwilling to drive and enhance independent and spontaneous travel capabilities for travelers with disabilities. One area of particular interest among public transit agencies is exploring the use of vehicle automation to overcome first- and last-mile mobility issues, possibly providing connections for all travelers to existing public transportation services or other transportation hubs (U.S. Department of Transportation, 2019).

Smart City Challenge - USDOT

In December 2015, the USDOT launched the Smart City Challenge initiative to increase cities' focus on the use of integrated data, technology, and innovation as tools for solving urban challenges related to mobility. USDOT took a different approach to grant-making by awarding the entire $40 million to a single city rather than allocating this funding to multiple jurisdictions (Shaheen et al., 2019). The purpose of the challenge was to encourage cities to deploy these tools to plan for increased urbanization and growth that will put a significant strain on cities' capacity to deliver basic services. Paul Allen's Vulcan Inc. joined USDOT's Smart City Challenge by committing an additional $10 million to the winning city chosen through a USDOT selection process (Shaheen et al., 2019). The idea behind this approach was to encourage cities to develop proposals with smart city pilots and compete for funding. Mid-sized cities were targeted for this competition as they were viewed as the cities with the greatest need for technology pilots and implementation (Cuddy et al., 2014)

The USDOT funding was intended to stimulate partnerships among the public sector, major institutions, and the private sector in the form of committed funds, in-kind contributions, and administrative streamlining. The Smart City Challenge is a notable example of a partnership between federal, state, and local governments and the private sector intended to move forward the core vision of MOD. Eighty-one cities submitted 78 proposals for the USDOT's Smart City Challenge (a few cities were part of larger regional submissions) (Shaheen et al., 2019). The winner of the Smart City Challenge was Columbus, Ohio. Columbus offered an array of shared mobility strategies. For example, one strategy Columbus implemented is an autonomous shuttle system that operates along a 1.4-mile route (Bringing Multi-Modal Trip Planning to the Columbus Region, 2019). The shuttle was in operation from December 2018 to September 2019. During its operational period, the shuttle provided 16,062 rides that covered 19,118 miles (Federal Highway Administration, 2020). The route was selected due to the low speed of the roads, low risk of deployment, the route's accessibility to local transit options, and the low impact to riders if there were route disruptions.

AV and SAV Trends

The increasing levels of vehicle automation have spurred research on emerging development trends in AVs and SAVs (Stocker and Shaheen, 2017). Existing development trends regarding AVs and SAVs include:

- SAV pilots are developing rapidly and preparing for public deployment, particularly pilots in low-speed and controlled environments. These developments will most likely lead to more SAV pilots within the coming years.
- Niche SAV markets and use cases are predicted to increase the speed of SAV deployment due to specially designed vehicles that do not need to provide ubiquitous transportation services.
- As SAVs transition away from having a trained tester onboard, they tend to rely on remote operations capabilities to maintain the safety of passengers.

Key Takeaways

- As vehicles become increasingly automated their impacts on the built environment, travel behavior, and society are uncertain but may result in positive or adverse impacts.
- The deployment of AVs and SAVs will most likely be influenced by existing and future ownership and business models.
- AVs and SAVs offer a variety of potential strengths, weaknesses, opportunities, and threats, and these possible outcomes may be guided by relevant policies for environment and land use, labor and economy, travel behavior, and social equity.
- Trends, such as the development of niche uses and remote operations, are predicted for the future development and use of AVs and SAVs.

Urban Air Mobility (UAM)

> **NASA's Urban Air Mobility (UAM) Vision**
>
> The National Aeronautics and Space Administration's (NASA) vision for urban air mobility (UAM) is to transform mobility around metropolitan areas by enabling a safe, efficient, convenient, affordable, and accessible air transportation system for passengers and cargo.

A variety of technological advancements in electrification, automation, and short and vertical take-off and landing (STOL and VTOL) are enabling on-demand aviation. These aviation innovations include new aircraft designs, services, and business models. While numerous societal concerns have been raised about these approaches (e.g., privacy, safety, security, social equity), these technologies have the potential to create new passenger mobility and goods delivery services in urban areas using small aircraft and piloted and pilotless aircraft. Collectively, these innovations are referred to as urban air mobility (UAM). Other common terms include rural air mobility, on-demand aviation, and advanced air mobility.

Between the 1950s and 1970s, several helicopter services began providing early UAM services in Los Angeles, New York City, San Francisco, and other communities. In recent years, on-demand aviation services similar to TNCs have entered the market. In New York City, BLADE provides helicopter services booked through a smartphone app. BLADE uses third-party operators that own, manage, and maintain their aircraft under Federal Aviation Administration (FAA) regulation 14 CFR Part 135, which governs intrastate air taxis and commuter services, including licensing and training of pilots and crews and required aircraft maintenance. BLADE passengers are required to check-in using valid government identification, and flier and baggage weight must fall within permissible limits.

In Los Angeles, SkyRyde operates similarly, linking passengers to pilots with privately owned four-passenger helicopters. SkyRyde is currently undergoing 14 CFR Part 135 certification. Additionally, Uber Copter has been testing on-demand helicopter service in New York City since 2016. In July 2019, Uber Copter made rides available to Uber Rewards members who have reached Platinum and Diamond status. The service can be booked up to five days in advance on the Uber app and offers eight-minute flights between Manhattan and the John F. Kennedy airport, typically costing $200 to $225 USD per person.

Similar helicopter services such as Airbus' Voom are operational in Mexico City, Sao Paulo, and the San Francisco Bay Area. Travelers can use Voom to request on-demand rides from partner air taxi companies. Trips can be booked anytime between one hour to 90 days in advance through the Voom app or website. Singapore is also supporting the development of electric vertical takeoff and landing (eVOTL) aircraft by constructing facilities to test UAV takeoff and landings. Programs, such as the U.S. Voluntary Airport Low Emissions (VALE) program, which provides funding to projects that support improved air quality at airports, may also support the development of eVOTL (Federal Aviation Administration, 2018c).

NASA's Advanced Air Mobility National Campaign

NASA's Advanced Air Mobility National Campaign aims to improve UAM safety and accelerate scalability through integrated demonstrations by hosting a series of UAM ecosystem-wide challenges beginning in 2020. The series of challenges will support the Federal Aviation Administration in developing an approval process for UAM vehicle certification; develop flight procedure guidelines; evaluate communication, navigation, and surveillance requirements; define airspace operations management activities; and characterize vehicle noise levels.

The first testing opportunity in the National Campaign will focus on the developmental testing of U.S. developed aircraft and will include airspace operations management services to explore architectures and technologies needed to support future safety and scalability of UAM operations. Participants selected for the developmental testing will have the opportunity to fly at NASA's Armstrong Flight Research Center at Edwards Air Force Base in Kern County, California, or a range of their choice, and participate in collaborative airspace operations simulations.

Developmental testing is the first step toward the National Campaign in 2022, which will involve broad industry participation, including domestic vehicle and airspace partners and international vehicle companies that will have the opportunity to fly more complex UAM aircraft operations at testing locations within the United States.

The first series of increasingly complex challenges will require participants to demonstrate safe operation of a piloted or remotely piloted aircraft capable of carrying a payload equivalent to at least one adult passenger within a complex simulated urban environment. Participants will test UAM technologies against key barriers to UAM integration in the U.S. national airspace, such as adverse weather, emergency landings, surveillance, loss of communication, and operations scheduling and routing. The scenarios developed for the National Campaign are designed to represent real-world UAM operations and address barriers for aircraft certification, operational safety, and community acceptance.

NASA's Advanced Air Mobility National Campaign is a subproject under the Aeronautics Research Mission Directorate's Advanced Air Mobility project. The National Campaign is structured to work with the UAM community to identify and address the key challenges to achieving NASA's vision for advanced air mobility.

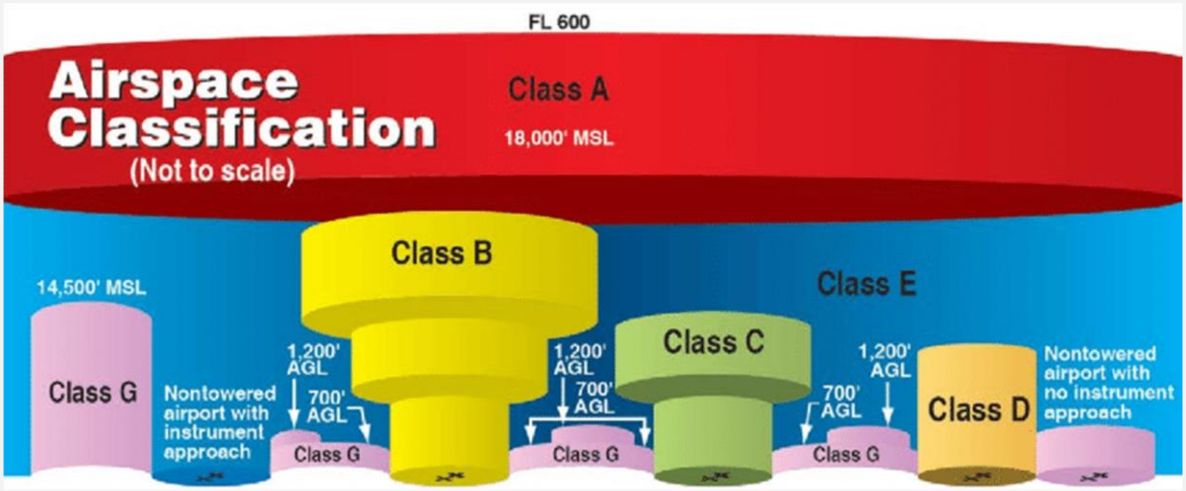
Airspace Classifications

Many community policymakers and planners without aviation experience, may not be familiar with airspace classifications, an area of aeronautical knowledge. The Federal Aviation Administration (FAA) has six airspace classifications (denoted by letters A-E and G). These classes are summarized below:

- *Class A:* Airspace 18,000 feet and above (up to Flight Level 600, approximately 60,000 feet). UAM should never fly in this space.
- *Class B:* This is airspace (generally up to 10,000 feet) around large airports with high levels of commercial traffic. All aircraft are subject to air traffic control.
- *Class C:* A busy airspace (typically 1,200 feet to 4,000 feet above airports) that is similar to Class B, with lower levels of traffic. All aircraft are subject to air traffic control.
- *Class D:* Airspace (generally up to 2,500 feet) around smaller and regional airports with control towers.
- *Class E:* This is all controlled airspace other than Class A-D. Typically, Class E extends from 700 feet to 1,200 feet above ground level (AGL) all the way to the beginning of Class A. In some areas, Class E may begin at the surface instead.
- *Class G:* Uncontrolled airspace. This is the only airspace where operators do not need to ask air traffic control permission to fly.

Airspace heights may vary by location. In many cases, UAs/drones will operate below 400 feet AGL. A FAA waiver is required to fly above this altitude. Typically, UAM aircraft with passengers will have a service ceiling of approximately 5,000 feet AGL; however, the service ceiling will vary by aircraft.

Figure 23. FAA Airspace Classifications



Source: faasafety.gov, n.d.

MSL: Mean Seal Level, AGL: Above Ground Level, FL: Flight Level

UAM Definitions

UAM may serve a variety of use cases including: disaster relief, goods delivery, and passenger mobility. Original equipment manufacturers (OEMs) are developing a variety of piloted, remote piloted, partially automated, and fully autonomous aircraft for a variety of applications. An examination of aircraft reveals differences in propulsion used (e. g., battery electric, hydrogen electric, hybrid, or gas-powered); design; technology; capacity; range; and compatibility with existing infrastructure. Table 25 summarizes frequently used terms and definitions related to UAM.

Table 25. Definitions and Common Terms

Term	Abbreviation	Definition
Systems		
Rural Air Mobility		An emerging concept envisioning a safe, efficient, accessible, and quiet air transportation system for passenger mobility, cargo delivery, and emergency management within or traversing rural and exurban areas.
Small Unmanned Aircraft System	Small UAS	Small unmanned aircraft and its associated elements (including communication links and the components that control the small unmanned aircraft) that are required for the safe and efficient operation of the small unmanned aircraft in the national airspace system.
Urban Air Mobility	UAM	An emerging concept that envisions a safe, efficient, accessible, and quiet air transportation system for passenger mobility, cargo delivery, and emergency management within or traversing metropolitan areas.
Unmanned Aircraft Systems	UAS	An aircraft and its associated elements operated with no human on-board; it may be remotely piloted or fully autonomous.
Unmanned Aircraft Systems Traffic Management	UTM	A traffic management system that provides airspace integration requirements, enabling safe low-altitude operations. UTM provides services such as: airspace design, corridors, dynamic geofencing, weather avoidance, and route planning. NASA proposes that UTM systems will not require human operators to monitor every aircraft continuously; rather, the system will provide data to human managers for strategic decisions.
Aircraft		
Small Unmanned Aircraft		An unmanned aircraft that weighs less than 55 pounds on takeoff, including everything that is on board or otherwise attached.
Unmanned Aerial Vehicles	UAV	UAVs are multi-use aircraft with no human pilot aboard, commonly referred to as “drones.” UAVs can be remotely piloted or fully autonomous. Devices used for cargo delivery typically have four to eight propellers, rechargeable batteries, and attached packages underneath the body of the UAV. Larger UAVs can be used to transport passengers as well.
Unmanned Aircraft	UA	An aircraft operated without the possibility of direct human intervention from within or on the aircraft. Commonly referred to as “drones.”
Vertical Take-Off and Landing	VTOL	An aircraft that can take off, hover, and land vertically.
Short Take-Off and Landing	STOL	An aircraft with short runway requirements for take-off and landing.

Source: Cohen et al., Forthcoming; 14 CFR 107.3

UAM can be classified according to the following characteristics:

- Design characteristics, such as passenger capacity, propulsion, airframe, or aircraft types (e.g., wingless designs, electric rotorcraft, aircraft that use any of its thrusters for vertical lift and cruise versus aircraft that use independent thrusters for vertical lift and cruise);
- Operational characteristics, such as VTOL and aircraft that can fly and be driven on roads (sometimes referred to as roadable aircraft);
- Training and knowledge requirements for pilots and operators;
- Airworthiness certification approaches, based in part or in whole on established FAA and international processes;
- Service type or use case (e.g., scheduled service, charter service, unscheduled service, passenger mobility, goods delivery, emergency management, etc.); and
- Distinctions based on piloted, remotely piloted/operated, and levels of aircraft automation (with respect to specific aircraft systems and phases of flight).

Source: (Booz Allen Hamilton, 2018)

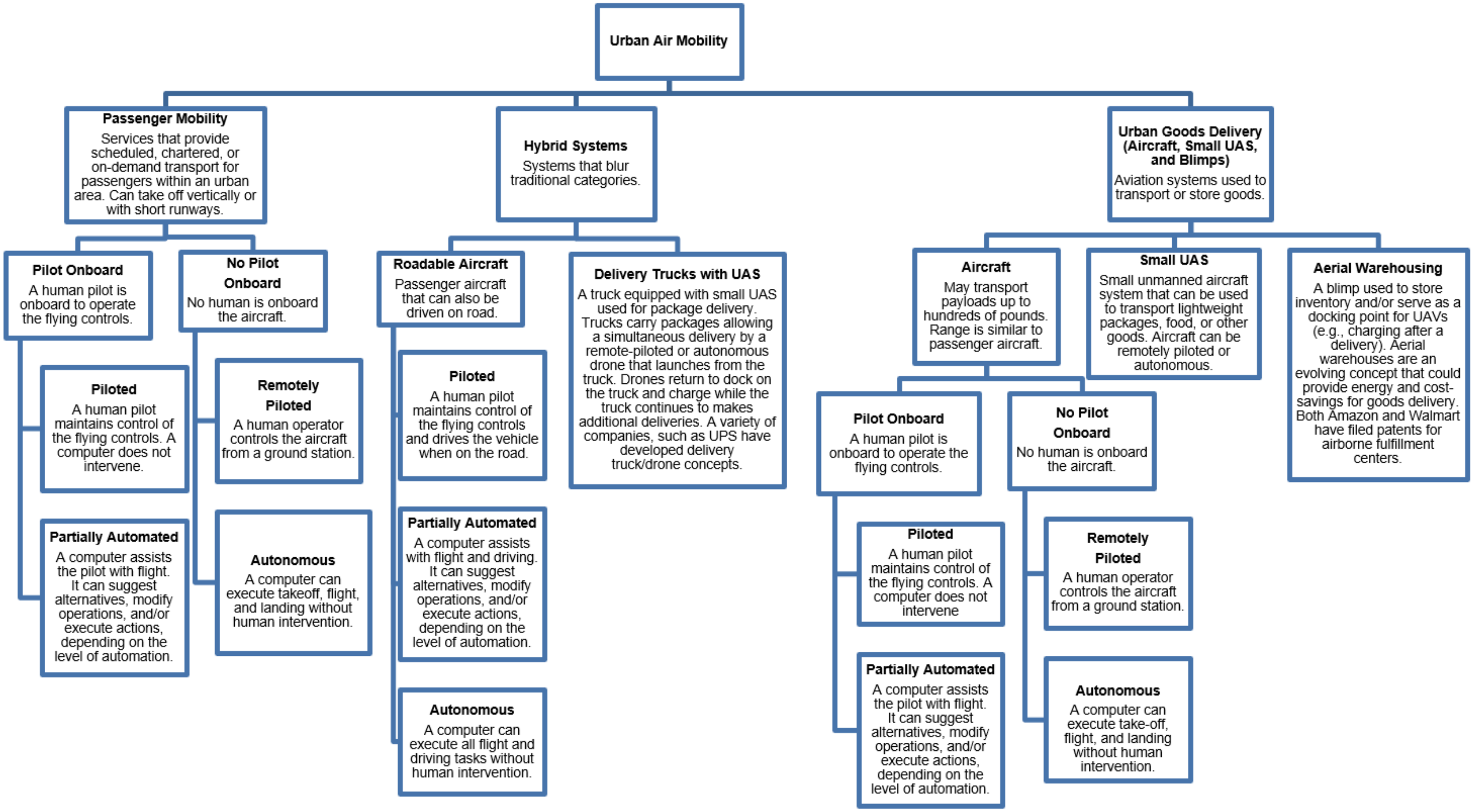
Figure 24 provides a taxonomy of UAM that blends these key characteristics with three broad use cases:

1) Passenger mobility comprised of aircraft and rotorcraft;
2) Urban goods delivery (comprised of a broad ecosystem of manned and unmanned delivery systems); and
3) Hybrid systems (intended to be a broad category used to describe systems that blur traditional categories, such as roadable aircraft, aerial warehousing concepts, and trucking/UAV systems).

Within each of these broad categories, distinctions can be made depending on whether there is a:

1) Pilot on-board, including fully piloted and partially automated flight (i.e., partially automating a particular phase of flight, such as take-off and landing);
2) The aircraft is remotely piloted or operated (e.g., operations centers with remote operators controlling multiple aircraft); or
3) The aircraft and/or unmanned aerial vehicles (often called UAVs or drones) are fully autonomous or pilotless.

Figure 24. UAM Taxonomy



Source: Cohen and Shaheen 2019; Cohen, Shaheen and Farrar, Forthcoming

Potential Concerns with UAM

Renewed interest in urban aviation coupled with innovative and emerging technologies has increased awareness about potential societal concerns associated with UAM. These concerns include:

- **Affordability/Social Equity:** Current UAM services are premium products. There are currently concerns that UAM services may not be an affordable transportation option by lower- and middle-income households and that UAM may be used by upper income households to buy their way out of congestion.

- **Visual Pollution:** An overcrowding of low-altitude aircraft in urbanized areas could create unwanted visual disturbances.

- **Noise Pollution:** Noise pollution is a potential problem that could arise with multiple low-altitude aircraft in urban areas.

- **Privacy and Increased Aircraft Activity Over Residential Areas:** Residential communities may be concerned with low-altitude aircraft flying over homes and yards due to concerns over safety, privacy, noise, and aesthetics (Finn and Wright, 2012).

- **Remotely Piloted and Autonomous Operations:** There are a variety of technical and operational challenges that must be overcome before UAM can be deployed at scale in urban areas. In particular, there could be community concerns associated with remotely piloted and autonomous aircraft (both from the perspective of users and non-users).

Research that seeks to understand the potential societal barriers can help identify challenges and mitigate potential concerns associated with UAM. Aerial goods delivery is discussed in further detail in the following section.

Skyports and UAM Infrastructure

Given the potential for UAM to grow over the next decade within the long-range planning horizons of many transportation agencies, communities may consider the potential impacts of UAM, how it may connect with other modes (such as public transportation), and general planning considerations for access/egress to skyports and mobility hubs with UAM.

The location of skyports can be influenced by a variety of factors, such as airspace considerations, land use, geographic context, weather patterns, existing infrastructure, social equity concerns, and operational requirements. Communities may consider overlay zoning as a regulatory tool to establish a special zoning district for UAM that can be placed over existing zones (i.e. base zones) to either limit building heights and/or preserve approach paths for either planned or potential skyports under consideration. The overlay district can share common boundaries with the base zone or fall across several base zone boundaries. Regulations or incentives could be attached to the overlay district to encourage particular types of skyports within a special area – such as a skyport within a radius of an existing or planned transit station or along a transit corridor. Overlay zones can also be used to encourage UAM mobility hubs by reducing development requirements (such as parking standards, setbacks, etc.) to support new construction near multimodal facilities.

Skyports

UAM aircraft use skyports (sometimes also referred to as vertiports) for takeoff and landing. Typically, skyports consist of three classifications of infrastructure based on their size and intended level of flight activity:

- *Vertipad:* A single landing pad and parking stall intended to accommodate one parked aircraft.
- *Vertiport:* A single landing pad, intended to accommodate two to three parked aircraft.
- *Vertihub:* Two or more landing pads with parking for multiple aircraft.

Figure 25. Vertipad

Source: Volocopter, n.d.

Figure 26. Vertiport

Source: Lilium Aviation, n.d.

Figure 27. Vertihub

Source: Pickard Chilton, n.d.

Skyports can have a variety of amenities specific to their design, placement, and built environment. Key considerations should include: airspace access; aircraft parking, charging, and battery swapping; facility security; and open access to accommodate a variety of aircraft types, operators, and users. In addition, the design of skyports can include multimodal services for parking, charging, and last-mile delivery, such as drones, lockers, and small robots. Potential considerations and characteristics for multimodal skyports are summarized in Table 26.

Table 26. UAM Skyport Typologies and Characteristics

	Characteristic	Description	Vertipad	Vertiport	Vertihub	Optional
Procedures	Policies	Complies with noise and environmental ordinances and regulations	✓	✓	✓	
Procedures	Schedule	Has the capacity to run a large number of flights per hour (e.g., eight-minute turnaround)		✓	✓	
Procedures	Safety	Implements procedures to ensure the safety of passengers and pilots	✓	✓	✓	
Typology Capacity	Open Access	Provides open access to a variety of UAM users and aircraft types	✓	✓	✓	
Typology Capacity	Small	A single landing pad and parking stall intended for one aircraft	✓			
Typology Capacity	Medium	A single landing pad, parks two to three aircraft		✓		
Typology Capacity	Large	Two or more landing pads, parking for multiple aircraft			✓	
Aviation Logistics	Electricity	Has adequate infrastructure for aircraft charging and/or battery swapping		✓	✓	
Aviation Logistics	Boarding	Area reserved for aircraft boarding		✓	✓	
Aviation Logistics	Waiting	Space reserved for passengers to wait comfortably		✓	✓	
Aviation Logistics	Office	Office for pilots and/or ground staff	✓	✓	✓	
Aviation Logistics	Sustainable Design	Environmentally friendly design techniques used, such as daylighting and use of photovoltaic solar panels				✓
Aviation Logistics	Green Space	Green spaces integrated within and outside of facilities				✓
Aviation Logistics	Verticality	Developed in a vertical structure to allow for efficiency with flight departure and landings				✓
Aviation Logistics	Modular	Designed modularly so skyport infrastructure can standalone or connect to create a larger facility	✓			

UAM skyports offer a potential opportunity for integration with existing or new mobility hubs. A few features and considerations for skyport mobility hub planning are summarized in Table 27.

Table 27. UAM Skyports as Mobility Hubs

	Characteristic	Description	Recommendation
Transportation Services	Electric Vehicle Charging	Offers charging stations for electric vehicles	Ensure that electric vehicles have adequate space to park and charge
Transportation Services	Parking	Offers parking options for manned and automated vehicles	Provide traditional parking spaces for both manned and unmanned vehicles
Transportation Services	Connectivity	Connects to a variety of transportation modes in order to bridge first- and last-mile gaps and act as a mobility hub	Work with a variety of agencies to offer multiple transportation modes and timed transfers
Transportation Modes	Open Access	Provides open access to a variety of UAM operators and service types (e.g., passenger mobility and goods delivery)	Public sector should consider policies that require UAM infrastructure to be publicly accessible by multiple UAM operators and users
Transportation Modes	Shared Micromobility	Designates room for bikesharing and scooter sharing services	Delineate spaces for bikesharing and scooter sharing services, both docked and dockless
Transportation Modes	Public Transit	Connects to other modes of public transportation	Provide space for multiple modes of transportation including dedicated curbspace, public transit stops, and accessible ramps
Transportation Modes	On-Demand Services	Loading zones for TNCs and microtransit	Delineate curbspace for different forms of transportation
Available Amenities	Dining	Offers on-site dining options	Promote the active use of space through on-site dining options
Available Amenities	Retail	Houses a variety of stores for retail opportunities	Offer retail opportunities that people can use during transit transfers or can access through public transit
Available Amenities	Entertainment	Provides entertainment options	Encourage active use of space by offering a diversity of entertainment options
Available Amenities	Athletics	Offers space for athletic activities	Foster community engagement by providing space for athletic activities and events
Available Amenities	UAS Delivery	Uses unmanned aerial systems (UAS) to complete last-mile delivery of packages and food	Deploy UAS systems from mobility hubs to complete last-mile delivery
Available Amenities	Robotic Delivery	Uses robots to complete last-mile delivery of packages and food	Work with local delivery services to deliver to hubs, shortening last-mile delivery
Available Amenities	Grocery Shopping	Contains grocery and convenience stores	Foster community engagement and local businesses by implementing locally operated grocery and convenience stores
Use of Space	Work Environment	Designates space for collaborative working environments	Offer the necessary amenities for workspaces to encourage active use during business hours
Use of Space	Events	Offers event space	Offer variety of transportation options to increase the accessibility for events
Use of Space	Community	Provides space for community gathering	Promote the use of space through community-oriented events

Emergency Helicopter Landing Facility (EHLF) Requirement – Los Angeles, CA

Prior to 2014, the City of Los Angeles Emergency Helicopter Landing Facility (EHLF) fire code required that every high-rise building have an approved emergency helicopter landing facility. The policy that had been in effect since the 1970s, has resulted in a high-level of helipads in the city's densest areas. However, because the emergency helipads were not intended to operate as a private use helistop or heliport, no notice for an airspace evaluation was required to be filed with the FAA. However, the requirement to construct helipads could make Los Angeles ready for UAM in the future.

Key Takeaways

- Advancements in electrification, automation, and vertical takeoff and landing are contributing to the development of advanced air mobility, such as UAM and rural air mobility.
- Renewed interest in urban aviation coupled with innovative and emerging technologies has increased awareness about potential societal concerns associated with UAM. These concerns can include affordability, visual pollution, noise pollution, privacy, and safety concerns.

Innovative and Emerging Last-Mile Delivery Technologies

Changing consumer behavior coupled with new delivery technologies could continue to transform consumer preferences and travel behavior through goods delivery (Ganzarski, 2017). This section discusses three potential transformative and disruptive last-mile delivery technologies:

- **Unmanned Aircraft (UA):** An aircraft operated without the possibility of direct human intervention from within or on the aircraft that delivers food or packages;
- **Delivery Robots:** Short-range, unmanned, ground-based devices that deliver food or packages; and
- **Automated Delivery Vehicles (ADVs):** Medium-range, automated (at least Level 4 automation), vehicles that deliver food or packages to businesses and consumers.

In general, last-mile delivery technologies are dispatched on-demand when a customer requests an order. Typically, both retailers and customers can track a delivery technology's location during the delivery process through a smartphone app or web interface. For security, the cargo bay of delivery robots and ADVs are mechanically locked throughout the journey and can only be opened by the recipient through their smartphone or an unlock code sent to the intended recipient. Each of these delivery applications are discussed in greater detail in the sections that follow.

Unmanned Aircraft Systems (UAS) and UAS Traffic Management Pilot Program

Retailers and logistics companies are experimenting with unmanned aircraft (UAs), commonly referred to as drones, to test a variety of aerial delivery applications and use cases (Amazon, 2019). A few use cases that have been tested using drone delivery include fast food delivery in urban areas, delivery of medical supplies in rural areas, and the delivery of 3D-printed tools to offshore ships (Matthews, 2019). Aerial delivery using drones could have a number of potential impacts, such as safety risks for aviation, concerns about user safety (e.g., potential interaction between untrained delivery recipients and drones), and concerns about aesthetic and visual pollution (Druehl, 2018). Interagency collaboration may be needed to address a variety of operational issues (e.g., airspace considerations, permissive use, operation standards, regulation, landing locations) (Shaheen et al., 2017).

Federal Aviation Administration (FAA) and UAS Regulation

The FAA has begun developing policies and programs to guide and support the use of UAS. As the demand for drone use below 400 feet increases, the FAA, NASA, and industry partners will need an Unmanned Aircraft System Traffic Management (UTM) infrastructure to operate safely and efficiently. UTM is a community-based traffic management system, where operators are responsible for the coordination, execution, and management of operations with rules established by the FAA (Federal Aviation Administration, 2019b). UTM relies on industry's ability to supply air traffic control services in areas where services are not provided by the FAA. The FAA plans to use UTM to support flight operations, primarily for small (less than 55 pounds) drones operating in low-altitude airspace. The FAA has developed two key initiatives to expand the use of drones and to safely and fully integrate this technology into the national airspace.

Unmanned Aircraft (UA) – Aircraft operated without the possibility of direct human intervention from, within, or on the aircraft.

Small Unmanned Aircraft – Unmanned aircraft weighing less than 55 pounds on takeoff, including everything onboard and attached to aircraft.

Unmanned Aircraft System (UAS) - Unmanned aircraft and associated elements, including communication links and the components that control the unmanned aircraft, which are required for the pilot in command to operate safely and efficiently in the national airspace system.

(FAA Modernization and Reform Act of 2012)

The first initiative, the UAS Traffic Management Pilot Program (UPP), was established in 2017 to identify an initial set of industry and FAA capabilities required to support flight operations for small unmanned aircraft operating in low-altitude airspace (Federal Aviation Administration, 2019c). The UPP will help identify services, roles and responsibilities, information architectures, data exchange protocols, software functions, and performance requirements for managing low-altitude drone operations without intervention by air traffic control facilities. In January 2019, the FAA announced the selection of three FAA UAS Test Sites to partner with the agency in the UPP – Nevada Institute for Autonomous Systems (NIAS), Northern Plains UAS Test Site (NPUASTS), and the Virginia Tech Mid Atlantic Aviation Partnership (MAAP) (Federal Aviation Administration, 2019a). The results from the UPP will provide a proof of concept for UTM capabilities currently in research and development and will provide the basis for initial deployment of UTM capabilities.

The second initiative, the UAS Integration Pilot Program (IPP) has brought state, local, and tribal governments together with private sector entities, such as UAS operators or manufacturers, to accelerate safe drone integration (Federal Aviation Administration, 2018a). The program is helping the USDOT and the FAA develop new rules that support more complex low-altitude operations by:

- Identifying ways to balance local and national interests related to drone integration;
- Improving communications with local, state, and tribal jurisdictions;
- Addressing security and privacy risks; and
- Accelerating the approval of operations that currently require special authorizations.

FAA Regulations and Certification Processes

The FAA certifies the design of aircraft and components that are used in civil aviation operations in the U.S. The FAA grants certifications based on the operational areas and service types of applicants. Interstate, foreign, overseas, or mail carrying applicants receive an air carrier certificate, while intrastate transportation applicants receive an operating certificate. Certification types are also based on service types – on-demand or commuter (scheduled). Communities with on-demand aviation services should understand the regulations and certification processes in these parts of Title 14 of the CFR:

- *Part 23:* Airworthiness standards for normal airplanes
- *Part 25:* Rules governing airworthiness standards
- *Part 27:* Airworthiness standards for normal rotorcraft (i.e., helicopters)
- *Part 29:* Airworthiness standards for transport helicopters
- *Part 91:* General operating and flight rules (general aviation)
- *Part 107:* Designed to allow the use of small UAS weighing up to 55 pounds
- *Part 121:* Rules for scheduled air carriers (i.e., regional and major airlines)
- *Part 133:* Rules governing external load operations for helicopters
- *Part 135:* Rules for commuter and on-demand operations (i.e., corporate, government, all helicopter operations)

Part 135 is a common certification pathway for on-demand aviation services involving passenger mobility and goods delivery. Part 135 regulates aircraft requirements, instrument flight rules (IFR), visual flight rules (VFR), recordkeeping, staffing, training, and safety procedures. Additional requirements and special conditions may apply.

IPP has created a meaningful dialogue on the balance between local and national interests related to drone integration and provides actionable information to the USDOT on expanded and universal integration of drones into the National Airspace System. The IPP has funded nine lead participants that are evaluating a host of operational concepts, including package delivery, flights over people and beyond the pilot's line of sight, night operations, detect-and-avoid technologies, and the reliability and security of data links between pilot and aircraft (Federal Aviation Administration, 2018a). These projects are summarized in Table 28. Fields that could benefit from the program include commerce (e.g., last-mile delivery), photography, emergency management, agricultural support, and infrastructure inspections.

Table 28. FAA UAS IPP Lead Projects

Lead Participant	Location	Project Application
Choctaw Nation	Durant, OK	• Agriculture • Infrastructure • Public safety inspections
City of San Diego	San Diego, CA	• Border protection • Food delivery • International commerce • Smart City/automated vehicle interoperability and surveillance
Innovation and Entrepreneurship Investment Authority	Herndon, VA	• Package delivery in urban and rural areas
Kansas Department of Transportation	Topeka, KS	• Facilitation of precision agriculture operations
Memphis-Shelby County Airport Authority	Memphis, TN	• FedEx aircraft inspection • Support of airport operations (e.g., security)
North Carolina Department of Transportation	Raleigh, NC	• Drone delivery in local communities
North Dakota Department of Transportation	Bismarck, ND	• Expansion of UAS nighttime operations • Expansion of UAS beyond visual line of sight (BVLS) operations
City of Reno	Reno, NV	• Delivery of time-sensitive, life-saving medical equipment in urban and rural settings
University of Alaska – Fairbanks	Fairbanks, AK	• Pipeline inspection in remote areas • Surveying in remote areas

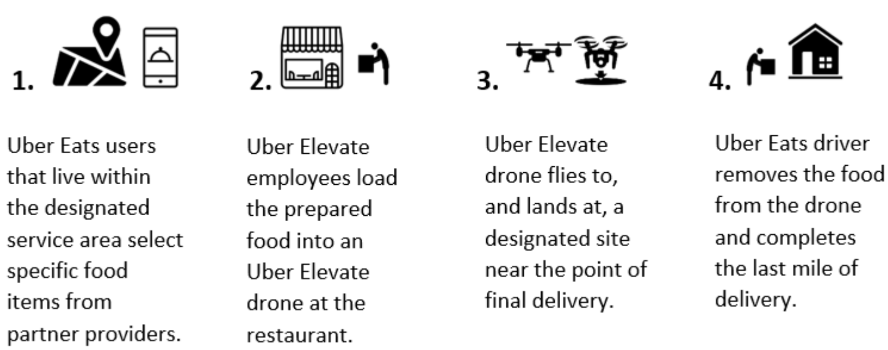
In October 2019, the FAA awarded a Part 135 air carrier and operator certification to UPS Flight Forward, a partner in the UAS IPP project in North Carolina. This certification allows the company to perform revenue-generating package deliveries under federal regulations and grants the company permission to operate multiple drones under their single certificate. UPS Flight Forward is working on delivering healthcare supplies to hospitals in the Raleigh, North Carolina area.

San Diego's Food Delivery Pilot

One of the IPP's lead participants, San Diego, is exploring potential uses cases for UAS, such as delivery of medical supplies, support functions for emergency responders, testing automated vehicle communication, and food delivery (Chadwick, 2018). San Diego is partnering with a variety of institutions and organizations in exploring potential UAS use cases.

In 2018, San Diego approached Uber Elevate to partner for a UAS IPP application to assist in the development of a UAS food delivery proof of concept under FAA Part 135 operations. As part of this partnership, Uber Elevate internally partnered with its Uber Eats division to help identify a restaurant partner and a UAS vendor to procure a UAV/drone suitable for food delivery. Uber selected McDonalds as the initial food vendor to collaborate with because of the company's interest in innovation, global presence, and large customer base. Locally, San Diego and Uber are partnering with San Diego State University (SDSU), and the surrounding area, to test this delivery service. Uber uses the following multistep process to deliver food with drones:

Figure 28. Uber Elevate Delivery Service



Source: Shaheen, Cohen, Broader, Davis, and Farrar, 2019

The pilot is intended to provide lessons learned for Uber Elevate's broader urban air mobility initiative by providing a sandbox to test its backend software. The partnership between San Diego and Uber Elevate allows San Diego to test UAS applications and provides Uber with a better understanding of the opportunities and challenges that exist offering on-demand aviation services (Holley, 2019). Uber Elevate plans to initiate air taxi services using eVTOL aircraft in the mid-2020s.

Figure 29. Delivery Robots

Source: OstapenkoOlena/iStockphoto.com, n.d.

Delivery Robots

A number of startups and logistics providers are developing and employing delivery methods using delivery robots. Two types of delivery robots are being developed and deployed:

- **Small delivery robots** approximately the size of a beverage cooler weighing less than 100 pounds intended to operate at pedestrian speeds on sidewalks (Figure 30).
- **Larger delivery robots** approximately the size of a bicycle, intended to operate up to 15 miles per hour in bicycle lanes or with vehicle traffic on low-speed streets (Figure 31).

Figure 30. Small Delivery Robot

Source: Joe Flood, 2017

Figure 31. Large Delivery Robot

Source: Refraction AI, 2019

Delivery robots can expand goods access to customers, but research on delivery robots is limited. While the effects are not well studied, delivery robots may reduce vehicular and parking congestion if they reduce the number of trips by larger last-mile delivery vehicles, but could also create congestion, modal conflicts, and accessibility challenges for pedestrians and people with disabilities on narrow or crowded sidewalks (Bandoim, 2019; Hu, 2019). Laws and regulations governing delivery robots sometimes refer to the devices as conveyance bots and personal delivery devices (PDD). Typically, these laws and regulations restrict or limit operational characteristics such as:

- **Ability to Operate** (e.g., complete prohibition or prohibition in specific locations)
- **Device Weight** (e.g., no more than 100 pounds)
- **Rights-of-Way Management** (e.g., devices may only travel on sidewalks and crosswalks)
- **Speed Limits** (e.g., no more than 10 miles per hour)
- **Human Supervision** (e.g., devices must always be capable of remote monitoring and control by a human operator)
- **Safety Features** (e.g., designed with a braking system)
- **Insurance Coverage** (e.g., minimum coverage of $10,000)
- **Enforcement** (e.g., for violating key regulatory provisions).

Laws and regulations tend to exclude specific size dimensions of delivery robots, communication methods between robots and pedestrians, data collection and storage standards, best practices for interactions with vulnerable populations (e.g., older adults, people with disabilities), and collision avoidance systems (Marks, Forthcoming). Due to the fact that sidewalks are typically regulated by local and regional agencies, there are no federal regulations governing delivery robots in the public right-of-way (Marks, Forthcoming).

As of April 2019, eight states have passed laws regulating delivery robots (Arizona, Florida, Idaho, Ohio, Utah, Virginia, Washington, and Wisconsin) (Albrecht, 2019; Autonomous Delivery Devices; n.d.; Brinklow, 2017). Local communities may also establish regulations regarding delivery robots in the rights-of-way. Communities such as Austin, Texas; San Francisco, California; Walnut Creek, California; and Washington, D.C. have developed their local regulations in the absence of state laws.

Ordinance 244-17 (Autonomous Delivery Devices) – San Francisco, CA

In 2017, San Francisco's Board of Supervisors passed an ordinance regulating robotic delivery devices. The ordinance sets forth the following requirements:

- **Ability to Operate:** In order to operate a device, an operator must submit an application for a 90-day permit for operation of a total of nine automated delivery devices, with the option for up to two 90-day extensions, after which operators will need to reapply for a permit. An operator may only operate a maximum of three devices at a time;
- **Device Weight:** No specifications;
- **Rights-of-Way Management:** Devices can operate on sidewalks and in designated zones;
- **Speed Limits:** Devices can operate at a maximum of three miles per hour;
- **Human Supervision:** Human operators must maintain a physical proximity of 30 feet to the device when operating the device;
- **Safety Features:** Operators must report GPS or photographic data on operations, information on businesses using robotic delivery, incidents related to public safety, and public complaints monthly;
- **Insurance Coverage:** No specifications; and
- **Enforcement:** A Department of Public Works staff member must be allowed to attend at least one operation within the permit period.

Source: Department of Public Works, 2017

Automated Delivery Vehicles (ADVs)

While robotic delivery provides point-to-point delivery service, ADVs are designed to serve multiple customers on a route. Similar to robotic delivery, ADVs are being tested and piloted for last-mile deliveries of groceries, fast food, and parcels. ADVs could provide an opportunity to reduce delivery costs through automation and economies of scale (e.g., more deliveries per a vehicle trip than smaller delivery mechanisms) (Dysart, 2018). Three types of ADVs include:

- **Fully Automated Delivery Vehicle (ADV):** Fully automated delivery vehicles (using level 4 or level 5 automation) operate with limited to no supervision by a delivery driver. Level 5 ADVs may be designed to operate without a driver altogether. However, human couriers could be required for some delivery use cases, such as vehicle-to-door services where a courier must deliver a package within a building or obtain a signature. In the future, fully automated delivery vehicles could be paired with smaller delivery robots to reduce reliance on human labor. In addition to automated vehicles designed specifically for deliveries, personal automated vehicles could deliver food and packages through peer-to-peer delivery business models (e.g., similar to CNS using personally owned AVs).

- **Semi-Automated Delivery Vehicle:** A semi-automated delivery vehicle (primarily Level 3) performs some driving tasks under the supervision of a delivery driver. The delivery driver can perform occasional tasks while in transit (e.g., scanning packages, coordinating with customers on pick-up, etc.).

- **Automated Delivery Vehicle with Lockers**: An ADV with lockers acts as an automated delivery vehicle that also incorporates mobile delivery lockers. Customers are notified in advance of the exact time of delivery, then pick up their delivery using a unique unlock code from a locker on the side of the vehicle.

Source: Joerss et al., 2016

Figure 32. ADV with Locker

Source: Boxbot, 2019

Automated Vehicle Grocery Delivery Service from Kroger and Nuro – Scottsdale, AZ and Houston, TX

Between August 2018 and March 2019, Nuro piloted an automated grocery delivery service in Scottsdale, Arizona with Fry's Food Stores. The Scottsdale pilot demonstrated the flexibility and potential benefits of ADVs, as well as consumers' willingness to try innovative technologies (Hawkins, 2018a). In April 2019, Nuro and Kroger launched an automated grocery delivery service in Houston, Texas (Redman, 2019). Early testing of the service used an on-board safety monitor that will be phased out by the end of 2019. Deliveries cost a flat fee of $5.95 and are delivered in automated Toyota Priuses (Gillespie, 2019).

ADVs are commonly regulated under the same rules as AVs, either by legislation or executive order. Some communities, such as Arlington, Texas and Austin, Texas have launched ADV pilot programs. In May 2019, California's Department of Motor Vehicles (DMV) announced that they may consider a separate class of testing for automated light-duty delivery vehicles (Descant, 2019).

Potential Concerns with Last-Mile Delivery Vehicles

While innovative last-mile delivery vehicles have the potential to increase access to goods, there are concerns over the potential impacts of these delivery options. Potential impacts of emerging last-mile delivery modes include:

- **Affordability:** Fees for emerging last-mile delivery modes may not be affordable for certain populations, such as low-income households.
- **Access:** Last-mile delivery devices themselves, or the platforms used to access them (e.g., websites, smartphone apps), may be inaccessible for certain users, such as people with disabilities; households without smartphone, Internet or credit/debit card access; and older adults.
- **Increased Congestion and Rights-of-Way Access:** An increasing number of last-mile delivery vehicles, robots, and drones can increase street, curbspace, and airspace congestion. Additionally, an increasing number of services may create competition for rights-of-way management.
- **Impacts on Pedestrians, Cyclists, and People with Disabilities:** Automated delivery vehicles and delivery robots could create conflicts with active transportation and block ADA access (e.g., loading zones, ramps, etc.) for people with disabilities.
- **Visual Pollution:** An overcrowding of robots and drone deliveries could create unwanted visual disturbances in urbanized areas.
- **Noise Pollution:** Noise pollution is a potential problem that could arise with additional delivery vehicle, robot, and drone use. For example, with drones the sound of spinning rotors may be tolerable in a single unit but create additional disturbances when multiple aircraft fly overhead.
- **Privacy:** Drones are capable of highly advanced surveillance and are already used by law enforcement. They may be equipped with various types of equipment, such as live-feed video cameras, infrared cameras, heat sensors, and radar. This can raise a number of concerns for privacy and civil liberties.
- **Infrastructure Maintenance:** Increased use of infrastructure from more delivery devices could require increased maintenance of infrastructure such as roadways, sidewalks, curbs, and landing pads.

More research is needed to understand the impacts of these emerging modes and potential mitigation measures.

Key Takeaways

- Innovations in last-mile delivery technologies (e.g., robotic delivery, ADVs, UAS) may disrupt goods delivery in a number of ways, such as competing for space in the public right-of-way (both surface and airspace) and potentially creating the need for new regulations.
- Last-mile delivery innovations also may result in a variety of impacts including congestion, noise and visual pollution, privacy concerns, and equity challenges.
- Laws regulating the use of emerging last-mile technologies could be implemented at the federal, state, or local level, but in many cases, have not been widely adopted.
- The FAA is guiding and supporting the use of UAS through the UAS Traffic Management Pilot Program (UPP) and the UAS Integration Pilot Program (IPP).

CHAPTER 7: Conclusion

Changing consumer preferences – coupled with advancements in technology, social networking, location-based services, wireless services, and cloud technologies – are contributing to transportation innovation and the growth of MOD. MOD is a concept based on the principle that transportation is a commodity where modes have distinguishable economic values. MOD allows customers to access mobility, goods, and services on demand and can support an integrated and multimodal operations management approach that can influence the supply and demand sides of a marketplace. The supply side of the marketplace consists of the providers, operators, and devices that offer transportation services for people or goods and service delivery. The demand side of the marketplace is comprised of travelers and goods, including their choices and preferences.

The MOD ecosystem is enabled by an array of stakeholders in a variety of disciplines. Common MOD stakeholders include public agencies at the local, regional, state, and federal levels of government, private companies, non-governmental organizations, academic institutions, and consumers. MOD stakeholders can engage in a variety of public-private partnerships (e.g., data sharing, gap-filling services, and others) to expand access to MOD. Stakeholders can plan and prepare for MOD by incorporating shared modes into transportation planning and modeling. In addition to planning and modeling the impacts of MOD, transportation network managers and systems operators can leverage MOD for transportation systems management and operations (TSMO) to aid in managing supply and demand.

Shared mobility services, such as carsharing, microtransit, shared micromobility (bikesharing and scooter sharing), and transportation network companies (TNCs) typically result in a variety of travel behavior, environmental, land use, and social impacts, often influenced by the environment in which they are implemented. Other innovative and emerging modes, such as urban air mobility (UAM), shared automated vehicles (SAVs), and last-mile delivery innovations (including robots, automated delivery vehicles, and drones) have not been extensively studied.

While MOD can be employed in a variety of built environments, partnerships, policies, and deployment characteristics are almost always tailored to local context. Communities are leveraging a number of common partnerships, such as first- and last- mile services, low-density service, off-peak service, and paratransit to help bridge spatial and temporal gaps in the transportation network. Policies integrating shared mobility into the public rights-of-way, zoning for new and existing developments, and multimodal integration (including fare and digital integration) can create a network effect multiplying the effectiveness of MOD. Pilot project evaluations may allow communities to study and assess the impacts of MOD.

The impacts of MOD on data privacy, equity, and labor are common concerns associated with on-demand mobility. Sharing traveler information can help enable integrated services, such as fare payment and trip planning. However, sharing MOD data may result in a variety of challenges (e.g., protecting traveler privacy). Many of these challenges may be mitigated through strategies, such as developing universal reporting standards, data security, and data aggregation. Additionally, MOD can enhance access and opportunities for underserved communities, but it may also have adverse impacts if a particular population or community bears a disproportionate share of the benefits or adverse impacts of MOD. Equity concerns may be understood through the STEPS framework to identify and mitigate spatial, temporal, economic, physiological, and social barriers. Communities may be able to overcome equity barriers through policies and programs that enhance access to unbanked and underbanked communities (households without debit or credit card access), providing alternative access mechanisms for digitally impoverished households, and providing accessible physical and digital services for people with disabilities.

MOD is creating new employment opportunities in some sectors of the transportation industry but is also disrupting existing labor in other transportation sectors where demand for other services have declined, such as taxis and liveries. In addition to changing the number and types of jobs available, MOD is also disrupting traditional labor practices, contributing to the growth of part-time, flexible schedule, and independent contractor work. Labor regulations coupled with workforce development may help communities leverage the potential benefits of MOD on labor while mitigating potential disruption, such as anticipated job losses associated with vehicle automation.

Developments in vehicle automation, electric aviation, and last-mile delivery are enabling new services and business models that could have a variety of impacts (both positive and negative) on communities. While the effects of these and other technological innovations on auto ownership, land use, parking, equity, and travel behavior remain to be seen, what is clear is that these innovations could have a disruptive impact on travelers and society. However, as these technologies come online, policymakers may need proactive policy to facilitate socially desirable outcomes. Leveraging the case studies, findings, current practices, and potential policies in this document can help stakeholders to:

- Engage in public-private partnerships to bridge gaps in the transportation network;
- Prepare communities by integrating MOD into current planning and modeling practices;
- Manage network supply and demand through MOD strategies, such as TSMO;
- Integrate shared mobility with existing transportation services in a variety of built environment types to support multimodal trips for all users;
- Prepare for the potential impacts of MOD through a variety of public policies;
- Integrate shared mobility and delivery services through mobility hubs, integrated fare payment, and information integration;
- Prepare for, and respond to, the impacts of MOD on labor and equity through data sharing, pilots, and research; and
- Prepare communities for innovative and emerging transportation technologies, such as AVs, SAVs, UAM, UAS, delivery robots, and ADVs.

Table 29 provides some key takeaways from this report.

Table 29. Key Takeaways

Thematic Concept	Key Takeaways
MOD Key Concepts	• Consumers are increasingly assigning economic values to modes and engaging in multimodal decision-making processes based on a variety of factors including cost, travel time, wait time, number of connections, convenience, and other attributes. • Rather than making decisions between modes, mobility consumers can make decisions among modes, in essence "modal chaining" to optimize route, travel time, and cost.
Stakeholders and Partnerships	• A number of stakeholders are involved in, influenced by, or affected by MOD. Stakeholders can have a variety of similar and differing roles, such as regulating MOD at various levels of government; providing mobility and delivery services; providing or linking to public transportation; providing information and fare payment services; and managing transportation networks. • Stakeholders can engage in a variety of partnerships to provide new, and enhance existing, transportation services. Public agencies may be able to leverage public-private partnerships to address a variety of challenges, such as bridging service gaps, improving paratransit, and sharing data.
Integrating MOD into Transportation Planning, Modeling, and Operations	• State, regional, and local public agencies can integrate MOD into long-range plans, short-range improvement programs, location-based plans, and issue-based plans to prepare for current and future changes in transportation. • Incorporating MOD in transportation modeling may be difficult due to traditional data collection and modeling methods (i.e., modes are excluded from traditional travel surveys and new supply and demand management strategies may be too complex to model given existing data limitations). • Several strategies that may be employed to enhance modeling include: incorporating travel data from shared mobility providers; including shared mobility in data collection (e.g., surveys) and models; collecting data more frequently; and using off-model analysis methods. • Communities can leverage transportation systems management and operations (TSMO) approaches to manage supply and demand across the transportation network.
Shared Mobility Implementation and Community Integration	• Shared mobility may result in a variety of impacts on travel behavior, the environment, land use and society. More research is needed to understand the impacts of shared modes in different contexts. • Shared mobility can be implemented in a variety of built environments, such as 1) City Center; 2) Suburban; 3) Edge City; 4) Exurban; and 5) Rural. • An increasing number of shared modes and operators can impact the rights-of-way in a variety of ways. Potential adverse impacts can be mitigated through strategies that manage and allocate

Thematic Concept	Key Takeaways
	rights-of-way access among service providers (e.g., curbspace management, loading zones, and parking policies). • Incentive zoning, such as increased development density and parking reduction for the inclusion of shared mobility, is one MOD implementation strategy. • Multimodal integration can improve connectivity and traveler convenience and can be achieved through the physical co-location of mobility services, integrated fare payment across modes, and information integration, such as trip planning apps and multimodal aggregators. • The growth of delivery services may result in a variety of impacts, such as competing for rights-of-way access, increasing congestion, and disrupting trip chains.
MOD Implementation Considerations	• Pilots provide opportunities for public agencies to test innovations, validate the feasibility of deployments, measure the impacts of services, and evaluate public policies that could impact MOD. • MOD may be able to enhance accessibility for underserved communities, but it may also have adverse impacts if a particular population or community bears a disproportionate share of the benefits or adverse impacts of MOD. • The STEPS Framework (Spatial, Temporal, Economic, Psychological, and Social) can be used by stakeholders to identify, prevent, and mitigate potential equity barriers to accessing MOD. • MOD is impacting transportation labor in a variety of ways, such as creating demand for new jobs while disrupting others. • Collecting, storing, sharing, and analyzing MOD data can be challenging for a variety of stakeholders. Developing data sharing and management standards can help public agencies leverage the potential opportunities data can provide while also protecting consumer privacy and proprietary information.
Innovative and Emerging Mobility Futures	• Developments in vehicle automation and changes to existing business models are evolving to include automated vehicles (AVs) and shared automated vehicles (SAVs). • Innovative and emerging last-mile delivery options, such as robots, automated delivery vehicles (ADVs), and unmanned aircraft systems (UAS) (i.e., drones) have the potential to disrupt on-demand delivery services. • A variety of technological advancements are enabling innovations in on-demand aviation, such as new aircraft designs, services, and business models. Collectively, these innovations are referred to as urban air mobility (UAM). Other common terms include rural air mobility, on-demand aviation, and advanced air mobility.

Thoughtful planning and implementation, continued research, and continued study of the impacts of MOD on communities will be necessary to balance commercial innovation with public goals and maximize the potential of these innovations.

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Academic and Non-Governmental Organizations

3 Revolutions – https://3rev.ucdavis.edu

3 Revolutions Future of Mobility Program is the innovative mobility research and policy outreach division of University of California's Institute of Transportation Studies at UC Davis. 3 Revolutions' research activities includes analyzing and simulating future transportation scenarios, developing forecasts and simulation models to predict impacts of innovative mobility, and analyzing environmental, economic, and equity impacts of emerging transportation trends.

Center for Advanced Multimodal Mobility Strategies and Education at the University of North Carolina Charlotte – https://cammse.uncc.edu

The Center for Advanced Multimodal Mobility Strategies and Education is a transportation research consortium of five major universities representing North Carolina (University of North Carolina at Charlotte), Texas (University of Texas at Austin and Texas Southern University), Connecticut (University of Connecticut), and Washington (Washington State University – Pullman). Their research aims to support economic development, reduce congestion, promote safety and social equity, preserve the environment, and significantly improve mobility of people and goods while preserving the existing transportation system.

Connected Cities for Smart Mobility toward Accessible and Resilient Transportation (C2SMART) at New York University – http://c2smart.engineering.nyu.edu

C2SMART, a research consortium consisting of New York University, Rutgers, University of Washington, University of Texas at El Paso, and The City College of New York, partners with cities and state stakeholders to pioneer innovative technological strategies to pressing transportation problems, with the goal of technology transfer from the research phase into the real world. Areas of focus include connected and autonomous vehicles, shared mobility, urban analytics, and secure sharing of big data.

Eno Center for Transportation – www.enotrans.org

The Eno Center for Transportation is a neutral, nonpartisan think tank promoting policy innovation and providing professional development opportunities to transportation professionals.

Frontier Group – www.frontiergroup.org

Frontier Group provides research and analysis to help citizens address a range of issues, including fracking, solar energy, global warming, transportation, and clean water.

Innovative Mobility Research – http://innovativemobility.org

Innovative Mobility Research conducts research on technology applications, behavioral response, and public policies that seek to expand and enhance transportation choices, better manage demand for transportation services, and improve the environment.

Institute for Transportation and Development Policy – www.itdp.org

The Institute for Transportation and Development Policy works with cities worldwide to develop transport strategies that cut greenhouse gas emissions, reduce poverty, and improve the quality of urban life. The Institute has offices in Argentina, Brazil, China, India, Indonesia, Mexico, and the United States.

Living Cities – www.livingcities.org

Living Cities is a member organization of foundations and financial institutions that works with leaders in cities across the United States to improve the economic well-being of low–income people.

Mineta Transportation Institute at San Jose State University – http://transweb.sjsu.edu

The Mineta Transportation Institute conducts research, develops education programs, and facilitates information and technology transfer focusing on multimodal surface transportation policy and management issues.

Mobility21 National University Transportation Center at Carnegie Mellon University – http://mobility21.cmu.edu

Mobility21 is a multi-disciplinary transportation research collaboration among Carnegie Mellon University, the University of Pennsylvania, the Ohio State University, and the Community College of Allegheny County. Mobility21's primary mission is research, with focus areas including innovative transport technologies and analytical tools, assistive technologies for people with disabilities, and increasing access to quality transportation for underserved communities. Pilot deployment and technology transfer are goals for all their research projects. Mobility21 also facilitates education and workforce development and diversity initiatives.

Mobility Lab – http://mobilitylab.org

The Mobility Lab conducts research and provides best practices guidance to advocates related to the development of healthy, efficient, and sustainable transportation options. One of Mobility Lab's primary goals is to measure the impacts of transportation demand management services in Arlington County, Virginia.

National Center for Mobility Management – http://nationalcenterformobilitymanagement.org

The National Center for Mobility Management helps communities adopt transportation strategies that increase mobility options and promote health, economic development, and self-sufficiency. An initiative of the United We Ride program, the Center is supported through a cooperative agreement with the Federal Transit Administration and operates through a consortium between the American Public Transportation Association, the Community Transportation Association of America, and the Easter Seals Transportation Group.

National Institute for Transportation and Communities at Portland State University – https://nitc.trec.pdx.edu

The National Institute for Transportation and Communities is a research partnership of the University of Oregon, Oregon Institute of Technology, University of Utah, University of Arizona, and University of Texas at Arlington, led by Portland State University. The Institute's research is targeted towards action by decisionmakers and seeks to promote economic opportunity, improve health, and reduce inequality by developing tools to enhance data-driven decision making and optimize mobility for all. The Institute develops education programs and toolkits to produce a diverse, interdisciplinary workforce at all levels and ages.

Natural Resources Defense Council – www.nrdc.org

The Natural Resources Defense Council is an international environmental advocacy organization with a staff of over 500 lawyers, scientists, and other policy experts and more than two million members and online activists around the world working to ensure the rights of all people to air, water, and the wild.

PeopleForBikes – www.peopleforbikes.org

PeopleForBikes is a membership organization made up of individual riders, businesses, community leaders, and elected officials that works to promote bicycling.

Shared-Use Mobility Center – http://sharedusemobilitycenter.org

The Shared-Use Mobility Center is a public-interest partnership working to foster collaboration around shared mobility and helping to connect the growing industry with public transit agencies, cities, and communities across the country.

Small Urban and Rural Transit Center at North Dakota State University – https://www.surtc.org

The Small Urban and Rural Transit Center provides transit stakeholders, users, providers, suppliers, and agencies with research and workforce training focused on public transportation, mobility, and accessibility needs of small urban and rural locations in the Upper Midwest.

Small Urban, Rural and Tribal Center on Mobility at Montana State University – https://westerntransportationinstitute.org/wti-research-centers/small-urban-rural-and-tribal-center-on-mobility-surtcom/

The Small Urban, Rural, and Tribal Center on Mobility joins the Western Transportation Institute at Montana State University, Upper Great Plains Transportation Institute at North Dakota State University, and the Urban and Regional Planning program at Eastern Washington University into a single research organization focused on enhancing mobility in small urban, rural, and tribal communities. The organization also provides leadership, education, workforce development, and technology transfer on all transportation-related aspects of mobility for people and goods in the regions and communities it serves.

Sustainable Cities Institute at the University of Oregon – https://sci.uoregon.edu

The Sustainable Cities Institute targets sustainability-based research and education through applied research, teaching, and community partnerships. The Urbanism Next Center, a division of the Sustainable Cities Institute, focuses on the role of autonomous vehicles, e-commerce, and the sharing economy in the future development of the form and function of cities.

Transportation Research Board – www.trb.org

The Transportation Research Board (TRB) promotes transportation innovation and progress through research activities involving engineers, scientists, researchers, and practitioners from the public and private sectors and academia. TRB is one of seven major programs of the National Research Council, which is the principal operating agency of the National Academies and is jointly administered by the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

Transportation Sustainability Research Center at the University of California, Berkeley – http://tsrc.berkeley.edu

The Transportation Sustainability Research Center conducts analyses and evaluations to develop findings and recommendations for key transportation issues of interest to industry leaders and policy makers to aid in decision making. The Center is part of the Institute of Transportation Studies at the University of California, Berkeley.

University of California Center on Economic Competitiveness in Transportation – http://ucconnect.berkeley.edu

The University of California Center on Economic Competitiveness in Transportation serves as the University Transportation Center for federal Region 9, supporting the faculty of its consortium of five University of California campuses (Berkeley, Irvine, Los Angeles, Riverside, and Santa Barbara) and its affiliate, Cal Poly, Pomona. The Center pursues research aligned with the broad theme of promoting economic competitiveness by enhancing multimodal transport for California and the region.

United States Public Interest Research Group – www.uspirg.org

The United States Public Interest Research Group is a consumer group focused on consumer health and safety, financial security, and public participation.

Urban Mobility and Equity Center at Morgan State University – https://www.morgan.edu/umec

The Urban Mobility and Equity Center is a three-university research consortium including University of Maryland and Virginia Tech, led by Morgan State University. The Center's research specialties include planning and operation for transit, paratransit, and freight, economic planning for transportation, and government promotion of connected and automated vehicles. The Center provides educational programs and community outreach to offer technical assistance to communities and foster the next generation of transportation professionals.

Industry and Public Sector Associations

Aerospace Industries Association - https://www.aia-aerospace.org/

Aerospace Industries Association (AIA) is a trade association representing suppliers and manufacturers in the aerospace industry. AIA has over 340 member companies and strives to shape aerospace policy and support national security efforts.

American Association of State Highway and Transportation Officials – https://www.transportation.org

The American Association of State Highway and Transportation Officials (AASHTO) represents highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico. AASHTO, a nonprofit, nonpartisan association, represents all transportation modes, including air, highways, public transportation, active transportation, rail, and water. Among its role as a supporter of an integrated national transportation system, AASHTO issues standards for the design and construction of highways and bridges, materials, and many other technical areas.

American Institute of Aeronautics and Astronautics - https://www.aiaa.org/

The American Institute of Aeronautics and Astronautics (AIAA) is a professional society that represents experts in the field of aerospace engineering. The AIAA is the U.S. representative on the International Council of Aeronautical Sciences and International Astronautical Federation and, since 2015, has over 30,000 members from 88 countries. AIAA works towards fostering aerospace ingenuity and collaboration.

American Planning Association – https://www.planning.org

The American Planning Association (APA) represents the nation's urban planning professionals and organizes the American Institute of Certified Planners (AICP) professional certification. A champion of the development of vital communities around the world, APA has 42,000 members from 100+ countries.

American Public Transportation Association – https://www.apta.com

The American Public Transportation Association (APTA) represents a diverse membership of public sector organizations, large and small private companies that support bus and rail services worldwide, government agencies, metropolitan planning organizations, state departments of transportation, academic institutions, and trade media publishers. APTA serves members through public advocacy, information sharing, and association-led efforts to ensure that public transportation is available and accessible in communities across the country.

Association for Commuter Transportation – http://actweb.org

The Association for Commuter Transportation (ACT) is an international association and leading advocate for commuter transportation and transportation demand management policies. Members are served through advocacy, education, and networking events.

Association of Metropolitan Planning Organizations – http://www.ampo.org

The Association of Metropolitan Planning Organizations (AMPO), a nationwide nonprofit membership organization established in 1994, serves the needs and interests of transportation planning agencies responsible for metropolitan regions. AMPO offers its member MPOs technical assistance and training, conferences and workshops, frequent and informative print and electronic communications, research, a forum for transportation policy development and coalition building, and a variety of other services.

CarSharing Association – http://carsharing.org

The CarSharing Association is a membership organization that works to maximize the environmental and social impacts of the carsharing industry. Collectively, the Association represents more than 4,000 shared vehicles and 125,000 drivers.

Community Transportation Association of America – https://ctaa.org

The Community Transportation Association of America (CTAA) is a membership organization that advocates for access to safe, affordable, and reliable public transportation for all Americans, regardless of age, ability, geography, or income. CTAA has led a number of federal grants in the public and community transportation arena, offers informational resources, and hosts an annual conference featuring learning events and networking opportunities.

Community Air Mobility Initiative - https://www.communityairmobility.org/

The Community Air Mobility Initiative (CAMI) is a member organization that works to provide education and resources on air mobility to the public, decisionmakers, and the media. Member organizations support the adoption of personal aviation as a potential strategy to overcome transportation challenges.

General Aviation Manufacturers Association – https://gama.aero

The General Aviation Manufacturers Association seeks to foster and advance the general welfare, safety, interests, and activities of the global aviation industry. The Association serves a variety of advocacy roles, promoting a better understanding of the aviation industry and the important role the aviation industry plays in economic growth and activity and in serving the critical transportation needs of communities, companies, and individuals worldwide.

Institute of Transportation Engineers – https://www.ite.org

The Institute of Transportation Engineers (ITE) is an international membership association of more than 15,000 transportation professionals working in more than 90 countries to promote mobility and safety for all transportation system users. ITE fosters professional development and career advancement for its members, supports and encourages education, develops technical resources including standards and recommended practices, identifies necessary research, and facilitates networking and the exchange of professional information.

National Air Transportation Association – https://www.nata.aero/

The National Air Transportation Association (NATA) is a public policy group that represents the aviation industry and aviation service companies to the federal and local governments. NATA was founded in 1940 and now represents over 2,300 aviation businesses. The goal of NATA is to empower its members to manage safe and successful aviation businesses.

National Association of Counties – https://www.naco.org

The National Association of Counties (NACO) represents member county governments, with the goal of uniting America's 3,069 counties. NACO provides collective advocacy on national policy, educational outreach, research materials, sample ordinances, model programs, free reports and policy toolkits, data of all kinds, and informational resources.

National Association of City Transportation Officials – https://nacto.org

The National Association of City Transportation Officials (NACTO) is an association of 68 major North American cities and 11 transit agencies that seeks to raise the state of practice for street design that prioritizes transit and active transportation modes. Through policy resources, design guides, trainings, workshops, and networking events, NACTO empowers cities and transportation officials to lead on transportation policy at the local, state, and national levels.

National Association of Development Organizations – https://www.nado.org

The National Association of Development Organizations (NADO) is a membership organization for the nation's regional development organizations, providing advocacy, education, research, and training. NADO members work to elevate local and regional quality of life by promoting economic and community development across a variety of sectors, such as disaster resilience, infrastructure, workforce development, and transportation.

National League of Cities – https://www.nlc.org

The National League of Cities (NLC), representing more than 2,000 member cities of all sizes from across the United States, acts as a collective advocate for the nation's cities and their leaders. NLC hosts educational events and provides learning and networking events, opportunities for cost-saving partnerships, as well as research, best practices, and technical assistance for members.

North American Bikeshare Association – http://nabsa.net

The North American Bikeshare Association (NABSA) is a member association of micromobility system owners, managers, operators, and service vendors. NABSA facilitates collaboration, sharing of experiences and best practices, enhanced communication, and guidance on the new and fast growing micromobility industry.

Project for Public Spaces - https://www.pps.org/

The Project for Public Spaces (PPS) is a non-profit organization that helps individuals and organizations create and sustain public spaces that support a strong community, including designs for pedestrians, bicyclists, vehicles, and other transportation modes.

SAE International – https://www.sae.org

SAE International (initially established as Society of Automobile Engineers) is a global association of more than 128,000 engineers and technical experts in the aerospace, automotive, and commercial-vehicle industries. The organization focuses on voluntary consensus standards development and advocating for continuous professional development for engineers.

Vertical Flight Society - https://vtol.org/

The Vertical Flight Society, formerly the American Helicopter Society, Inc., is an international technical society for professionals working to advance vertical flight technology. The Vertical Flight Society is predominantly engineers and scientists who bring together industry, academia, and government.

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