Mobility on Demand

Operational Concept Report

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16. Abstract

This operational concept report provides an overview of the Mobility on Demand (MOD) concept and its evolution, description of the MOD ecosystem in a supply and demand framework, and its stakeholders and enablers. Leveraging the MOD ecosystem framework, this report reviews the key enablers of the system including business models and partnerships, land use and different urbanization scenarios, social equity and environmental justice, policies and standards, and enabling technologies. This review is mostly focused on the more recent forms of MOD (e.g., shared mobility).

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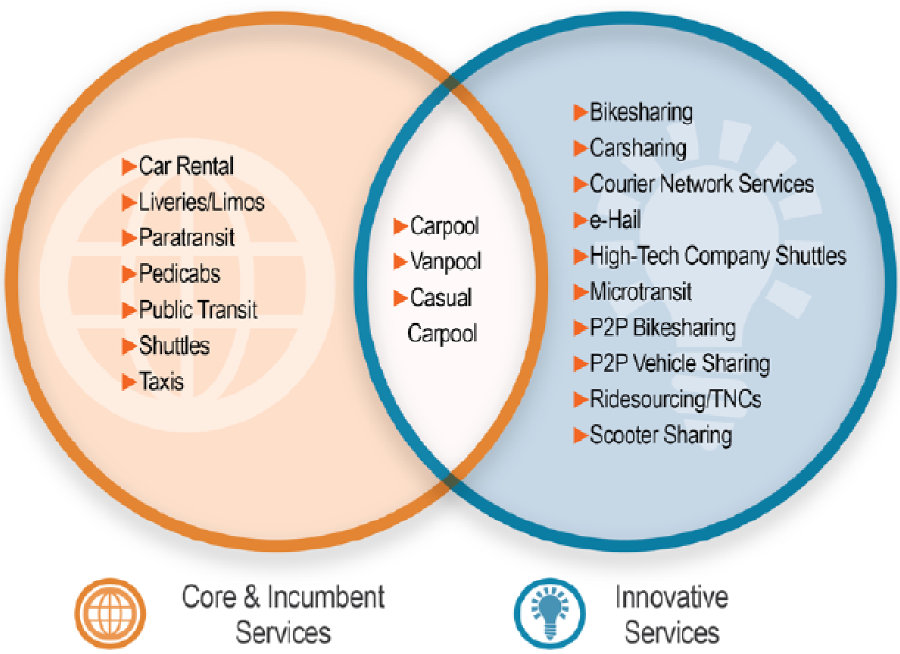
Executive Summary

Advancements in social networking, location-based services, wireless networks, and cloud technologies are contributing to the sharing economy. The sharing economy is a developing phenomenon based on sharing, renting, and borrowing goods and services, rather than owning them. The sharing economy has influenced many economic sectors including financial, goods, food, services, and transportation. Technological, mobility, and social trends are also changing the way people travel and consume resources.

Building on the recent advancements in sharing economy, **Mobility on Demand (MOD)** is an innovative transportation concept where consumers can access mobility, goods, and services on demand by dispatching or using shared mobility, courier services, unmanned aerial vehicles (UAVs), and public transportation solutions. The most advanced forms of MOD passenger services incorporate trip planning and booking, real-time information, and fare payment into a single user interface. Passenger modes facilitated through MOD providers include carsharing, bikesharing, ridesharing, ridesourcing/transportation network companies (TNCs), scooter sharing, microtransit, shuttle services, public transportation, courier network services (CNS) and delivery services, and other emerging transportation solutions. Figure 1 illustrates the complete shared mobility ecosystem.



Source: USDOT Report on Shared Mobility: Current Practices and Guiding Principles, March 2016

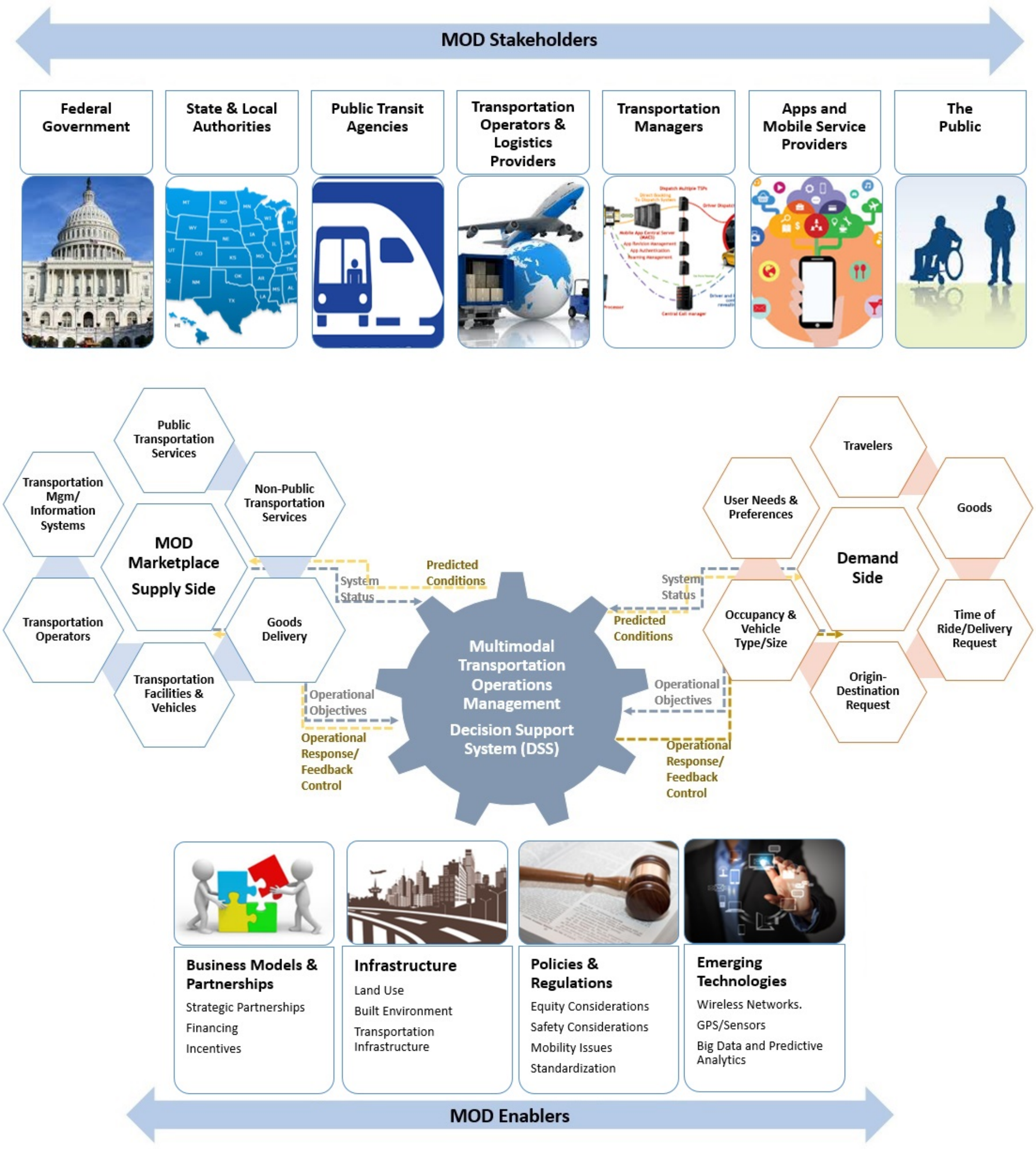
Figure 1: Shared Mobility Ecosystem

The most advanced forms of MOD courier services incorporate app-based and aerial delivery services (e.g., drones). Other popular terms associated with the MOD concept include mobility as a service

(MaaS) or transportation as a service (TaaS). MaaS differs considerably from existing definitions of MOD in that MaaS emphasizes mobility aggregation, smartphone and app-based subscription access, and multimodal integration (infrastructure, information, and fare integration). MOD encompasses a strong emphasis on both personal travel and goods delivery as it relates to commodified transportation services, as well as system management (i.e., supply and demand).

The U.S. Department of Transportation (USDOT) Mobility on Demand (MOD) Program is a multimodal program initiated by the Intelligent Transportation Systems (ITS) Joint Programs Office (JPO) and the Federal Transit Administration (FTA) to study emerging mobility services; public transit operations; goods delivery services; real-time data services; and ITS that can enhance access to mobility, goods, and services for all. The purpose of this *MOD Operational Concept Report* is to help guide MOD concept development, pilots, testing, demonstration projects, research, and public policy.

In recent years, passenger and courier MOD services have grown rapidly due to advancements in technology; changing consumer patterns (both mobility and retail consumption); and a combination of economic, environmental, and social forces. MOD is a new concept based on the principle that transportation is a commodity where modes have economic values that are distinguishable in terms of cost, journey time, wait time, number of connections, convenience, and other attributes. The MOD ecosystem (see Figure 2) demonstrates how USDOT vision of an integrated and multimodal transportation operations management approach can interact and/or influence the supply and demand sides and what the key enablers are. The components of the supply and demand sides are identified based on the concept of consumption choice and trip generation (i.e., the available options for travelers to accomplish their daily trips or for goods to be delivered, considering consumption and modal choices—e.g., destination, time, mode, route, lane, and facility). The supply side of this ecosystem consists of the players, operators, and devices that provide transportation services for people or goods delivery. The demand side consists of the system users (travelers and couriers) and their choices and preferences, which in turn affect the supply side as well. MOD provides response strategies (to the feedback from ecosystem components) that address new objectives; use existing facilities and services but with improved and broader integration; and leverage new systems, facilities, and services.



Source: USDOT, August 2017

Figure 2: MOD Ecosystem

This *MOD Operational Concept Report* was developed in recognition of this growing transportation phenomenon. MOD is rapidly changing due to advancements in technology and consumer behavior. This report presents current understanding at the time of this writing.

How to Use this Document

This *MOD Operational Concept Report* will be of value to individuals, businesses, public agencies, and local communities who want to know more about MOD and to public agencies interested in developing public policy in response to this growing transportation phenomenon. The report contains resources, information, and tools for local governments and public agencies seeking to implement emerging services or manage existing MOD services.

The following are some suggestions for this operational concept's use:

- *Access MOD resources.* Review findings from use cases highlighting challenges, opportunities, lessons learned, and best practices deploying MOD.
- *Guide strategic transportation planning.* How might MOD impact congestion, air quality, emissions, and parking? How could MOD enhance accessibility to passenger services and consumer goods? This report may be used to guide transportation planning and research needs across a spectrum of public agencies.
- *Aid public policy development.* What are the risks and opportunities presented by MOD and how can opportunities be leveraged and risks be managed?
- *Develop research agenda.* Review recommendations for future research needs across eight multi-disciplinary topic areas impacting and impacted by MOD.

The *MOD Operational Concept Report* builds on two earlier USDOT primers on shared mobility and smartphone applications:

- Shared Mobility: Current Practices and Guiding Principles[1] – This primer provides an introduction and background to shared mobility; discusses the government's role; reviews success stories; examines challenges, lessons learned, and proposed solutions; and concludes with guiding principles for public agencies. The primer provides an overview of current practices in this emerging field, and looks toward the future in the evolution and development of shared mobility.
- Smartphone Applications to Influence Travel Choices[2] – This primer provides an overview of current practices in this emerging field and looks toward the future in the evolution and development of smartphone applications for the transportation sector. The primer provides an introduction and overview of smartphone applications (known as "apps"); discusses the background, evolution, and development of smartphone apps; reviews the types of smartphone apps promoting transportation efficiency and congestion reduction; discusses transportation apps and their impacts on traveler behavior; examines current challenges; and concludes with guiding principles for public agencies.

[1] https://ops.fhwa.dot.gov/publications/fhwahop16022/fhwahop16022.pdf

[2] https://ops.fhwa.dot.gov/publications/fhwahop16023/fhwahop16023.pdf

Report Overview

This report is organized into the following 10 chapters:

- **Chapter 1** provides the background and overview of the MOD concept and ecosystem.
- **Chapter 2** discusses technological, mobility, and societal trends impacting MOD.
- **Chapter 3** explores the current state of the industry, and **Chapter 4** describes MOD and various built environments.
- **Chapters 5 and 6** discuss social equity considerations and policies and standards to enable MOD, respectively.
- In **Chapter 7**, the role of enabling technologies such as wireless and mobile data, location-based services, automated and connected vehicles, and other enablers are discussed in greater detail.
- Building on the review of MOD key enablers, **Chapter 8** provides a high-level discussion of performance measures for MOD and select programs and initiatives within the USDOT and other agencies that help advance the vision of the MOD program within the Department (**Chapter 9**).
- The report concludes with a discussion of future research needs to advance MOD (**Chapter 10**).

This operational concept report aims to provide an overview of the emerging field and current understanding of MOD—as in the years to come, it will continue to evolve and develop. In light of this evolution, ongoing research, tracking, and longitudinal analysis are recommended to support sound planning and policymaking in the future.

Key Takeaways

Table 1 describes the key takeaways identified through the development of this report.

Table 1: Key Takeaways

Chapter	Key Takeaway
Chapter 1: Background and Overview of the MOD Concept	• Technology, mobility, and societal trends are changing the way people travel and consume resources, disrupting both supply and trip chains all supporting MOD growth. This is also providing more choices on the supply side for both passengers and goods delivery. • MOD is an innovative transportation concept where consumers can access mobility, goods, and services on demand by dispatching or using shared mobility, courier services, UAVs, and public transportation solutions. • Common MOD stakeholders and partners often include public transit agencies, paratransit, MOD service providers, app developers, transportation and traffic managers, connected traveler services, metropolitan planning organizations, and local governments. These stakeholders along with the enablers of the system are helping to better define, form, and advance MOD to the next generation of a transportation system of systems.
Chapter 2: MOD and Shared Mobility	• MOD includes several core modal and delivery options primarily focused on shared mobility and goods delivery. • Shared mobility is having a transformative impact on many cities by enhancing transportation accessibility and mobility. • In recent years, consumption choice is disrupting traditional notions of trip generation and travel behavior patterns. Digital and goods delivery can enhance access to a wide array of goods and services.
Chapter 3: State of the Industry, Business Models, and Partnerships	• Several business models (e.g., Business-to-Consumer, Business-to-Business, Peer-to-Peer) have evolved to meet the diverse needs of consumers, service providers, and partners. Supporting MOD has numerous potential benefits for partner organizations (public or private), such as reducing parking demand, decreasing partner costs, and achieving environmental goals. Ultimately, the goal of partnering with MOD operators is to harness positive impacts (e.g., increased accessibility, reduced travel costs); reduce single-occupant vehicle (SOV) travel; and shift travel behavior in a way that helps reduce congestion and improve air quality. • Public agencies should explore opportunities for public and private collaboration. Public-private partnerships can support a more multimodal transportation network that enhances accessibility, livability, and quality of life.

Chapter	Key Takeaway
Chapter 4: Built Environments	• A close examination of U.S. urbanization patterns shows that most areas are comprised of five development types: 1) City Center; 2) Suburban; 3) Edge City; 4) Exurban; and 5) Rural. • In the densest urban areas, MOD has the potential to reduce demand for private automobiles and single-occupant travel, reduce demand and more efficiently manage parking, offer short-distance and medium-distance transportation alternatives to private vehicle use, and help urban centers mitigate congestion and emissions. • Urban area use cases may include first- and last-mile connections to public transportation; urban goods movement (e.g., CNS); daily commuting and other business trips; school trips; and trips for people with special needs, such as people with disabilities, caregivers, medical trips, etc. Additional use cases may include mobility for special circumstances, including special events and disaster response (e.g., evacuation). MOD may also mitigate public transit congestion during peak periods and offer late-night travel when public transit systems have reduced service. • Similarly, common suburban and edge city use cases may include first- and last-mile connections to public transportation, daily commuting and other business trips, school trips, trips for low-income and carless households, and trips for people with special needs, such as people with disabilities, caregivers, medical trips, etc. • The exurban and rural built environments are characterized by very low-development densities. Common use cases in these ultra-low-density areas may include access to: 1) resource-based jobs (e.g., farms, mining, etc.); 2) special needs populations (e.g., older adults, low-income and carless households, and people with disabilities); and 3) access to nearby airports and medical care.

Chapter	Key Takeaway
Chapter 5: MOD and Social Equity Considerations	• While environmental justice and social equity have been an important consideration for the transportation sector, there is limited statutory and regulatory guidance, as well as legal precedents on how these laws may impact private sector transportation modes, such as ridesourcing/TNCs. • Equity can be difficult to analyze because there are several types of equity issues impacting the transportation network. With the proliferation of private mobility services often requiring a smartphone, mobile internet access, and/or credit and debit cards, these services can raise a wide array of potential environmental justice and social equity issues including digital poverty, unbanked and-underbanked users, service access to low-density and rural areas, affordability, and access for older adults and people with disabilities. • MOD should enhance mobility, access, and economic opportunity for all travelers. MOD can raise equity concerns when users are required to have smartphones (or data networks) to access services, when fares are unpredictable or expensive, or when service is unavailable or inaccessible (e.g., low-density communities, older adults, or people with disabilities). • MOD can also create opportunities to enhance access and equity by providing increased mobility options (e.g., fares, routes), increased travel speed and reliability, critical first-and-last-mile connectivity, and expanded coverage to historically underserved users or communities. Legislation and regulation can play a notable role in safeguarding transportation equity by mitigating emerging MOD technological and access barriers, although more research and policy guidance is needed to clarify the applicability and scope of existing statutes.
Chapter 6: Relevant Policies and Standards to Enable MOD	• As MOD continues to grow and expand, the critical need to develop and manage public policy will also expand. • Policies and regulations can support innovation in MOD to enhance mobility, safety, and sustainability. In light of new services and innovations, state and local governments may need to re-evaluate current regulations for market entry, geographic coverage, extent of service, and service quality for traditional and innovative forms of MOD. This assessment should also include public safety requirements. • Policies and regulations should also address an array of equity issues, such as ensuring access for people with disabilities, unbanked and underbanked users, and people without access to smartphones or the mobile Internet. • Standardizing technologies, security and privacy, and open data standards could accelerate the pace of MOD growth and support multimodal integration.
Chapter 7: MOD Enabling Technologies	• Internet-based platforms, information and communication technology, location-based services, and big data are contributing to the growth of MOD. • The emergence of connected vehicles, automated vehicles, and smart infrastructure will continue to impact MOD. Data sharing and management will be integral not only to MOD growth but to the continued advancement of connected, automated, and other Internet of Things (IoT) applications.

Chapter	Key Takeaway
Chapter 8: Performance Measures	• Performance measures should be used as a measure of whether public policy goals are being achieved. • The performance measures, if used strategically, should identify whether improvements and progress have been made in safety, mobility, affordability, accessibility, and other key policy goals. • Performance metrics should be comparable with other modes (where applicable) for effective multimodal comparisons across the transportation network.
Chapter 9: MOD Programs within the USDOT and Other Agencies	• There are many ongoing programs contributing to the USDOT's vision of MOD. These initiatives have focused on specific aspects of MOD, such as technology, data-centric transportation integration, operations and management, policy and standards, and pilot programs. • For MOD programs to grow and evolve, it is critical to have close collaboration with key initiatives including but not limited to Integrated Corridor Management, Active Transportation and Demand Management (ATDM), Mobility Services for All Americans (MSAA), MOD Sandbox and Accessible Transportation Technologies Research Initiative (ATTRI) Programs. Moreover, close collaboration with other agencies, including Department of Energy, Department of Defense, Department of Labor, and others, will be instrumental to advancing the USDOT's MOD Program.
Chapter 10: MOD Research Needs	• The USDOT should consider eight core areas to support its research agenda for MOD: 1) Economic Impacts; 2) Travel Behavior Impacts (e.g., modal shift, auto ownership, energy, environment); 3) Energy and Environmental Impacts; 4) Social Equity and Environmental Justice; 5) Future of Mobility; 6) Policy and Regulations (e.g., land use, equity, finance, labor, tech transfer); 7) Data Management, Sharing, and Standardization; and 8) Transportation Planning.

Key Research Areas

Source: USDOT, August 2017

Figure 3: MOD Research Agenda

The *MOD Operational Concept Report* concludes with recommendations for future research covering eight core topic areas:

- *Economics:* There is a need to explore the economic impacts of MOD such as industry benchmarks, key economic indicators, and the macro- (e.g., gross domestic product) and micro-level (e.g., cost and time savings) impacts on public agencies and households, respectively.
- *Travel Behavior:* There is a need to understand the travel impacts of MOD and the commodification of the transportation services (e.g., shared modes, goods delivery). There is also a need to understand local and regional travel behavior impacts of MOD services.
- *Energy and Environment:* More research is needed to understand the full spectrum of MOD modal impacts on the environment and energy consumption. Current gaps in understanding include local and regional energy and environmental impacts and future impacts of connected and automated vehicles.
- *Social Equity and Environmental Justice:* There is a need to understand MOD service gaps, policy challenges, and policy opportunities to better serve statutory protected classes and vulnerable populations, such as people with disabilities, low-income communities, and minority communities.
- *Future of Mobility:* There is a need to understand how MOD will impact and be impacted by an array of emerging and future innovations in mobility and goods delivery, such as automated vehicles, aerial vehicles, delivery robots, drones, and other innovations.
- *Policy and Regulations:* More research is needed to understand ways that policymakers and regulations can enable more intelligent and efficient use of resources to achieve taxpayer savings and improve service delivery in support of innovation and government efficiency. More research is needed to understand the potential opportunities and challenges of these emerging technologies and to guide federal policy development.
- *Data Management, Sharing, and Standardization:* Data management, sharing, and standards are critical to the growth and success of MOD. There is a need to understand how data should be

managed, protected, and standardized to facilitate safe sharing and interoperability when necessary between public and private partners.
- *Transportation Planning:* More research is needed to support effective integration of MOD during the transportation planning phase (e.g., modeling, implementing MOD across an array of built environments, and other topic areas).

Key Terms Used in this Report

The following are key terms used throughout this report. A complete glossary is provided at the end of the document.

MOD is an innovative transportation concept where consumers can access mobility, goods, and services on demand by dispatching or using shared mobility, courier services, UAVs, and public transportation solutions. Passenger modes facilitated through MOD providers can include shared modes, public transportation, and other emerging transportation solutions (e.g., aerial taxis). Goods delivery facility through MOD can include app-based and aerial delivery services (e.g., drones).

Shared mobility is innovative transportation strategy that enables users to have short-term access to a transportation mode (e.g., vehicle, bicycle, or other low-speed travel mode) on an as-needed basis. Shared mobility includes various service models and transportation modes that meet the diverse needs of travelers. Shared mobility can include roundtrip services (vehicle, bicycle, or other low-speed mode is returned to its origin); one-way station-based services (vehicle, bicycle, or low-speed mode is returned to a different designated station location); and one-way free-floating services (vehicle, bicycle, or low-speed mode can be returned anywhere within a geographic area).

Preface

The USDOT is eager to understand how the growth of MOD and changes in travel behavior can help the nation reimagine the transportation network. Per the USDOT's vision, MOD is an innovative transportation concept, evolving around connected travelers, where consumers can access mobility and goods delivery services on demand by dispatching or using public transportation, shared mobility, courier services, UAVs, drones, and other innovative and emerging technologies. MOD's vision is to merge mobility and transportation systems management and operations, agencies, and private vendors, as well as all the users of the system contributing to demand. MOD is a new concept based on the principle that transportation is a commodity where modes have economic values that are distinguishable in terms of cost, journey time, wait time, number of connections, convenience, and other attributes.

The USDOT could leverage MOD to achieve its goals for managing or influencing different forms of mobility and delivery including:

- Improve the efficiency of the transportation system and increase the accessibility and mobility of all travelers
- Enable transportation system operators and their partners to monitor, predict, and influence conditions across an entire mobility ecosystem and for an entire region
- Embrace the needs of all users (travelers and shippers), public and private facilities, and services across all modes—including motor vehicles, pedestrians, bicycles, public transit, for-hire vehicle services, carpooling/vanpooling, goods delivery, and other transportation services
- Have the capacity to receive data inputs from multiple sources and provide response strategies geared to various operational objectives
- Incorporate appropriate higher-level municipal and regional objectives and interactions related to transportation system performance.

Given recent changes in the transportation supply and demand, along with advancements in transportation management and operations, MOD is a multimodal program initiated by the ITS JPO, Federal Highway Administration (FHWA), and FTA that is intended to study emerging mobility services, integrated public transit networks and operations, real-time data, connected travelers, and cooperative ITS that could enable a more traveler-centric, transportation system-of-systems approach. Such an approach could provide improved mobility options to all travelers and system users, including the movement of freight alongside people in an efficient and safe manner.

The USDOT has supported multimodal transportation operations research over the past decade in a wide range of areas including Connected Vehicles, MSAA, ATTRI, ATDM, Integrated Corridor Management (ICM), and next-generation Transportation Systems Management and Operations (TSMO) Decision Support System (DSS). These programs have collectively provided advanced tools and concepts that transportation agencies can use to manage and operate their traditional transportation services (e.g., highways, public transportation) using proactive transportation management and operation techniques. These advances provide the agencies a combination of tools for managing their systems, such as predictive analytics and multimodal demand and capacity management, dynamic and integrated DSS, and capability maturity frameworks for transportation technology implementations.

The ongoing evolution in MOD is enabling future TSMO (envisioned through concepts such as ATDM) to monitor, predict, and influence conditions across a mobility ecosystem. A fully multimodal transportation operations management approach reflects a system-of-systems that leverages all the current advances taking place in the transportation field. This is the next logical evolutionary step in an integrated transportation system management framework. Multimodal transportation operations management aims to expand the “macro-system” to include the entire mobility ecosystem—all goods and people that move throughout a region and all transportation modes and their operators and users within that region (including private sector logistics facilities and fleet operators, ridesourcing, and microtransit services, for instance). A key piece of this system is a regional DSS, which receives data inputs from multiple sources and provides response strategies to meet desired performance objectives.

This engine lies at the center of the MOD ecosystem, receives data from all portions of the system, assembles those data into an overall picture of current and predicted conditions, identifies problems considering a wide range of operational objectives applicable to the specific time period. Consequently, it draws upon pre-defined response strategies, identifies interventions to be made by the system manager(s) to address the problems, and ultimately generates and implements response and action plans dynamically. Ideally and as the system evolves, it will be able to dynamically generate and implement response and action plans optimized across a constantly changing array of outcomes from all areas of the transportation network, affecting a broad range of stakeholders that can vary in importance over time.

This multimodal transportation operations management system employs network/wireless communication and data analysis tools (i.e., technological enablers) to allow transportation-system operators and their partners to monitor, predict, and influence conditions across an entire mobility ecosystem. Its scope encompasses the needs of all users (travelers and shippers), as well as external stakeholders, and embraces public and private facilities and services across all modes.

In summary, the USDOT vision for a multimodal transportation operations management includes the following aspects:

- A system that embraces all modes and their operators and users across entire regions
- A system that embraces a greatly expanded set of operational objectives, which is integrated (encompassing the needs of surface transportation systems and their users) and holistic (acknowledging the wide reach of transportation, in terms of the number and diversity of stakeholders and their concerns)
- A system that would adopt a dynamic approach toward its objectives, allowing them to vary over time (different times of the day, different days) and space (different portions of the mobility system, specific modes or corridors or trip types)
- A system that would globally optimize across a dynamically changing array of transportation-related outcomes, affecting a broad range of stakeholders (beyond just travelers and shippers), which can vary in importance over time
- A system that provides response strategies (to the feedback from components of the ecosystem) that address new objectives; use existing facilities and services but with improved and broader integration; and leverage new systems, facilities, and services.

Recognizing the importance of multimodal transportation, the growth of MOD, and the commoditization of transportation services, the ITS JPO is pleased to present this *MOD Operational Concept Report*. Development of this report was made possible by the USDOT and public and private sector stakeholders who participated in the interviews. It is important to note, however, that this is a rapidly evolving field, which requires ongoing tracking and evaluation. This operational concept report represents current understanding at the time of publication, which will undoubtedly continue to evolve.

Chapter 1. Background and Overview of the MOD Concept

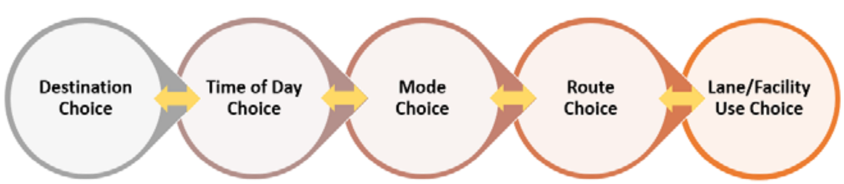
Disrupting Mobility

Advancements in social networking, location-based services, wireless networks, and cloud technologies are contributing to the sharing economy, also referred to as peer-to-peer (P2P) sharing, the mesh economy, and/or collaborative consumption. The sharing economy is a developing phenomenon based on sharing, renting, and borrowing goods and services, rather than owning them. The sharing economy has influenced many economic sectors including financial, goods, food, services, and transportation.

Technological, mobility, and social trends are also changing the way people travel and consume resources. These trends are disrupting traditional notions of trip generation, notably trip chaining (i.e., the linking of a series of destinations in one single-origin based tour), due to the many choices for travel and goods access. A break in the person-trip chain influences the overall transportation ecosystem and could impact the overall use of a particular travel mode, time of day of travel, or facility used. For example, travelers' decision to shift from a private vehicle to public transit for a commute trip, or 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 previous trip chain and trip generation behavior.

Trip Chain

The trip chain is the core principal of ATDM. One of its innovations and benefits is that it brings demand management strategies fully into the operations sphere, while traditional transportation demand management (TDM) has been primarily a strategic or planning activity. Like ATDM, MOD could be framed around the core principal of the trip chain, which represents a series of decisions that impact transportation demand and network use. It also represents the points at which MOD may influence travel activities. There are three forms of transportation network demands related to people and goods trips—traveler, transportation, and infrastructure. The trip chain as it relates to these types of demands could be simplified into the choices shown in Figure 4, which involve the what, where, when, and how of travel.



Source: USDOT, August 2017

Figure 4: Trip Chain

What is Mobility on Demand (MOD)

Mobility on Demand, or MOD, is a new concept based on the principle that transportation is a commodity where modes have economic values that are distinguishable in terms of cost, journey time, wait time, number of connections, convenience, and other attributes. MOD can improve the efficiency, effectiveness, and quality of transportation services through connecting public transit with new mobility options.MOD refers to a network of safe, affordable, and reliable transportation options when, where, and how travelers want it.

MOD encapsulates how people move, how households consume goods and services, and the spatial aspects of consumer decision making. MOD represents the evolution of our transportation system that reflects changing socio-demographics and integrates innovative practices, solutions, and models for the management of transportation supply and demand.

MOD promotes choice in personal mobility, leverages emerging and existing technologies and big data capabilities, encourages multimodal connectivity and system interoperability, and promotes new business models that enhance traveler experience.

MOD has three major guiding principles: traveler centric and consumer driven, data connected and platform independent, multimodal and mode agnostic. MOD is defined by quality and performance for each personal mobility choice. Technology does not change the MOD vision; it provides the capabilities to realize the interoperable vision. MOD also embraces all modes and resources for travel to support personal mobility choices in an integrated manner.

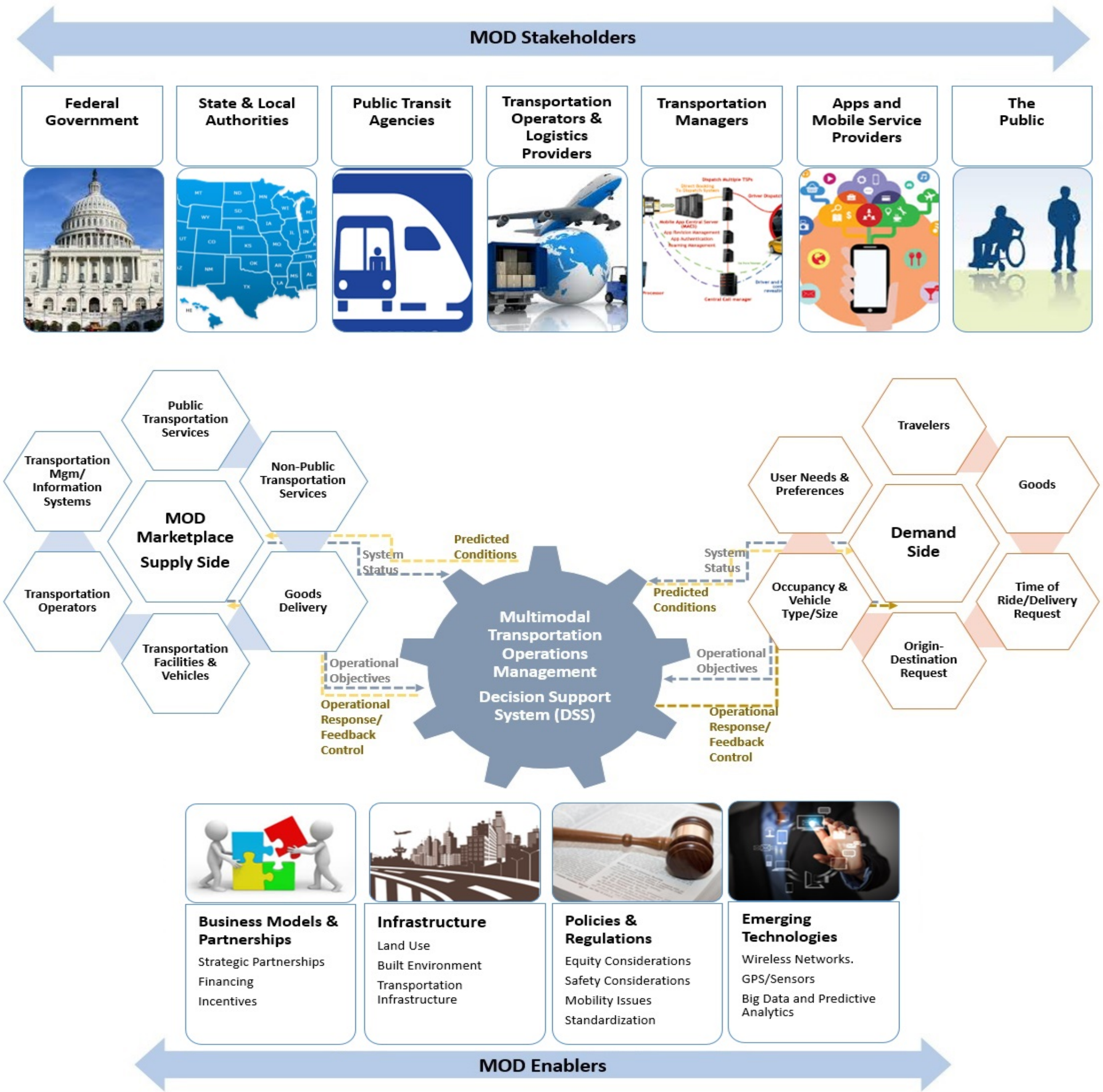
Per the USDOT's vision, MOD is an innovative transportation concept, evolving around connected travelers, where consumers can access mobility and goods delivery services on demand by dispatching or using public transportation, shared mobility, courier services, UAVs, drones, and other innovative and emerging technologies. This vision of MOD is to merge mobility and transportation systems management and operations, agencies, and private vendors, as well as all the users of the system contributing to demand.

Connected Travelers

Connected travelers are an important piece of the MOD evolution and include both people and vehicles that exchange data among themselves and other parts of the transportation infrastructure. As the data network has evolved, it has further enabled connectivity among travelers. People who have grown up with computers and the Internet—often termed "digital natives"—make up an increasing proportion of the workforce and society at large. As they are more attuned to information communications technologies (ICT), they tend to accept and even demand that it be integrated into their lives (Wang Q. C., 2008).

MOD Ecosystem

The USDOT is eager to understand how the growth of MOD and changes in travel behavior can help the nation reimagine the transportation network. To better understand how the USDOT could influence or be impacted by MOD, it is best to describe the MOD ecosystem in a supply and demand framework. The MOD ecosystem, Figure 5, demonstrates how the USDOT vision of an integrated and multimodal transportation operations management approach can interact and/or influence the supply and the demand sides and what the key enablers are. The multimodal transportation operations management receives input from the rest of the system and influences it through feedback control mechanisms that help manage supply and demand, and will play an increasing role in light of big data.



Source: USDOT, August 2017

Figure 5: MOD Ecosystem

The components of the supply and demand side are based on the concept of consumption choice and trip generation (i.e., for travelers to accomplish their daily trips or for goods to be delivered, what all the available options are, considering consumption and modal choices—destination, time, mode, route, lane and facility).

MOD Ecosystem – The Supply Side

The supply side of this ecosystem consists of all the players, operators, and devices that provide transportation services for people or goods delivery, including:

- Publicly-delivered transportation services such as public transit (trains, buses, ferries, paratransit)
- Non-public transportation services including taxis, car rentals, microtransit (Chariot, Via, etc.); ridesourcing (Lyft, Uber, Curb, etc.), personal vehicles, volunteer drivers, other shared services (e-Hail, carsharing, ridesharing, bikesharing, scooter sharing, etc.), and others (Chapter 2 provides more details on the shared mobility suppliers, which have a big contribution in emergence of MOD)
- Goods delivery services including freights, logistics, first-and-last mile goods delivery, CNS, UAVs, robotic delivery (Chapter 2 provides more background and information on delivery services that are affecting the traditional goods delivery systems)
- Transportation facilities including parking, tolls, roadways, and highways
- Vehicles of all types such as transit vehicles, private vehicles, goods delivery vehicles, and emergency vehicles that could be connected and autonomous in the near future
- Transportation management and information systems, such as payment systems for parking, toll and public transit, signal systems, mobile Apps for trip planning and payment (for all travelers), fleet management systems, and navigation systems
- Transportation information services, including schedule information, 511, and dynamic message signs, also information services provided by the private sector such as Waze and Google Maps.

MOD Ecosystem – The Demand Side

The demand side of this ecosystem consists of all the users of the system (travelers and couriers) and their choices and preferences, which in turn affect the supply side as well:

- All travelers, including pedestrians, riders, drivers, cyclists; this includes the spectrum of population including older adults, people with disabilities, children, etc.
- Goods and merchandise requiring physical delivery; digital delivery of some goods and services may be able to temper demand
- Time of ride and/or delivery request, which also affects the decisions on what mode to use as it depends on the availability of the particular service at a particular time
- Origin-destination request, which determines the location of the demand and affects the route and mode choice as well
- Modal demand based on occupancy, size, or type of vehicle requested
- User needs and preferences including mode and decision choices on how a trip is to be made (such as decisions to drive alone, carpool, use public transport, or some other form of shared

used mobility options). It also includes needs related to human service transportation for populations with special needs. Mode choice is a critical contributor to the overall transportation demand.

It is important to note that demographic makeup and changes (such as rising life expectancies and an aging population, retiring in place) in different regions may affect demand. For example, technology savvy travelers may make different mobility choices than the rest of the population. Moreover, there are more mobility and delivery options available for the consumers in dense urban environments versus suburban and rural areas, which affects the demand choices.

MOD Stakeholders

There is a wide range of stakeholders involved in, influenced by, or affected by MOD. MOD stakeholders can have a variety of similar and differing roles, such as: 1) commoditizing passenger mobility and goods delivery; 2) offering short-term, on-demand access to mobility and goods delivery solutions for users; 3) enhancing convenience by facilitating trip planning or delivery, payment, and other functions into a single interface; 4) providing convenience through additional on-demand mobility and delivery options; 5) providing transportation service to all including people with special needs; and 6) increasing mobility and goods availability (e.g., journeys previously inaccessible by a single mode, first-and-last mile connections, additional service offerings during off-peak or high-congestion travel times, and access to goods/services previously unavailable).

The stakeholders could be categorized as follows:

- ***Federal Government*:** Many branches of the government can influence MOD, including the USDOT, Department of Energy (DOE), Department of Labor (DOL), Department of Commerce (DOC), Department of Defense (DOD), among others. These organizations, albeit from different angles, can play a role in establishing transportation strategies, policies, and legislations. They can also implement those strategies and make investments in pilot programs, and provide guidance for nationwide development of strategies put forth.
- ***State and Local Authorities:*** These include regional and local governments, city municipalities, metropolitan planning organizations (MPOs), and local authorities. These entities play a role in implementing policy and regulations, issuing permits, managing public transport in the region, and improving transportation operations. They also provide strategic urban planning and traffic planning, and are responsible for the local infrastructure.
- ***Public Transit Agencies:*** These include all the agencies that provide public transportation including city buses, trolley buses, trams (or light train), rapid transit (metro, subway), ferries, and paratransit. This also includes human service transportation centers.
- ***Transportation/Traffic Managers:*** These include transportation management centers that monitor the operations, allocate resources as necessary, and respond to the needs of the network.
- ***MOD Operators***: These include operators of all forms of MOD services, public or private sector, that provide mobility or delivery services. They affect the MOD ecosystem, and are affected by its evolution.
- ***Transport Service Providers:*** These include bikesharing, car rentals, carsharing, ridesourcing, and microtransit and paratransit service providers. These are mostly part of the supply side of the ecosystem that have a stake in the success of MOD.

- ***Logistics Service Providers:*** These include logistics management 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 ICT services and providers enabling on-demand service, mobile ticketing, payment, and navigation services.
- ***Consumers:*** These are the ultimate end users of MOD services who affect the system by the type of demand and requirements they have. Chapter 3 includes a more robust discussion of some of the MOD stakeholders and partners.

MOD Key Enablers

MOD enablers are all the components that could enable the systems to work more efficiently and expand its benefits to more users. These enablers could be categorized as follows:

- **Business models and partnerships** include financing structures, incentive strategies, and strategic partnerships. Several MOD business models (e.g., business to consumer, business to government, business to business, and P2P) have evolved to meet the diverse needs of consumers, service providers, and partners. With different business models, there are also opportunities for different financing structures, which are needed both for maintaining the current forms of mobility and the emerging ones. Likewise, supporting MOD has numerous potential benefits for partner organizations, such as reducing parking demand, decreasing partner costs, and achieving environmental goals. Ultimately, the goal of partnering with MOD operators is to harness positive impacts (e.g., accessibility, less travel costs), improve network efficiency (by reducing SOV travel), and shift travel behavior toward modes that help achieve air quality goals. Chapter 3 provides more discussions around business models and partnerships in MOD with few examples.
- **Infrastructure enablers** comprise land use, the built environment, and transportation infrastructure (e.g., roads, sidewalks, rail tracks). The type of land use and built environment (e.g., urban, suburban, and rural) can greatly affect the operation of MOD and the extent of use. Similarly, the transportation infrastructure and how advanced and intelligent it is could positively affect the overall transportation system operations in terms of ease of use, duration, and cost of trips, among other factors. Chapter 4 provides more details on land use and different urbanization scenarios. Chapter 7 discusses smart infrastructure as part of technological enablers.
- **Policy and regulatory** include enablers such as equity, safety, mobility, sustainability, accessibility considerations, and standardization efforts. 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 urban and rural divide. Likewise, standardization (both technological and infrastructure) is crucial to ensure interoperability among different components of the system and to enable a more efficient and usable system. The public sector has a major role as a stakeholder and enabler affecting different transportation modes by defining legislative frameworks, ensuring fair market performance, establishing incentives, and initiating pilot programs. Chapter 5 and Chapter 6 provide more discussions on equity issues, policy and regulations, and standardization.
- **Emerging technologies** comprise enablers such as GPS, sensors, wireless systems, IoT, mobile apps, automated aerial vehicles (AAVs), UAVs, robotic delivery, big data, data analytics and management systems, machine learning, artificial intelligence, virtual reality, inclusive ICT, and universal design. Technology is a key enabler of this ecosystem and has enabled enhanced

connectivity among travelers, goods, services, and infrastructure, which is in turn enabling more efficient use resources and new transportation and consumption choices. Chapter 7 provides more details on technology enablers.

The following chapters provide a closer look at some of the key components of this ecosystem. This includes two of the key players in the supply side (e.g., shared mobility and goods delivery services), which have a bigger role in disrupting transportation. Additionally, the chapters discuss some of the key enablers (e.g., business models and partnerships; land use and built environments; social equity; policies, regulations and standardization) that play major roles in USDOT decision making to influence MOD.

The discussion around the enablers then shifts to performance measures (Chapter 8), as they are central to quantifying MOD progress. Chapter 9 then discusses the current activities within the USDOT and a few other governmental agencies that relate to MOD evolution, which provides an understanding of the focus and status of the research related to MOD. With that in mind and identifying the current gaps, Chapter 10 identifies key research areas to support the USDOT vision of MOD, which should be addressed in the future.

Key Takeaways

The key takeaways include:

- Technology, mobility, and societal trends are changing the way people travel and consume resources, disrupting both supply and trip chains—all supporting MOD growth. This is also providing more choices on the supply side for both passengers and goods delivery.
- MOD is an innovative transportation concept where consumers can access mobility, goods, and services on demand by dispatching or using shared mobility, courier services, UAVs, and public transportation solutions.
- Common MOD stakeholders and partners often include public transit agencies, paratransit, MOD service providers, app developers, transportation and traffic managers, connected traveler services, MPOs, and local governments. These stakeholders along with the enablers of the system are helping to better define and form MOD and advance it to the next generation of a transportation system of systems.

Chapter 2. MOD and Shared Mobility

Trends Leading to MOD

Transportation represents one of the six pillars[3] of the sharing economy (Owyang, 2014) and the second largest after housing/space. Numerous shared mobility and goods delivery services, such as Lyft, Zipcar, Postmates, and Instacart, have pushed MOD from the fringe to the mainstream. A trend is a recent development that is sustained in the public or private sector. It is often impacted by technology and other external forces (e.g., economy, politics, etc.). Three **key trends** disrupting the transportation marketplace and mobility (people and goods movement) are technology, mobility, and society.

Technological trends include:

- The growth of cloud computing, location-based/satellite navigation services, and mobile technologies
- The expansion of data availability, collection, sharing, aggregation, and re-dissemination through crowd-sourced, private, and public sector sources facilitated through application programming interfaces (APIs) and other third-party tools
- Ongoing development and deployment of advanced algorithms, machine learning, and artificial intelligence (AI), enabling on-demand and flexible route service offerings, electrification, and automation
- Advancement in augmented reality and virtual reality (VR) enabling many new forms of innovations
- The commodification of passenger travel, goods, and services driven by the growth of online commerce and app-based service offerings.

Mobility trends include:

- Increasing demand and associated congestion, reduced funding, and the need to maximize existing infrastructure capacity
- Growing popularity of shared mobility and shared modes, such as bikesharing and ridesourcing/ TNCs
- Increased focus and growth of flexible service characteristics, such as dynamic routing, on-demand service, and a variety of vehicle sizes and types.

Societal trends include:

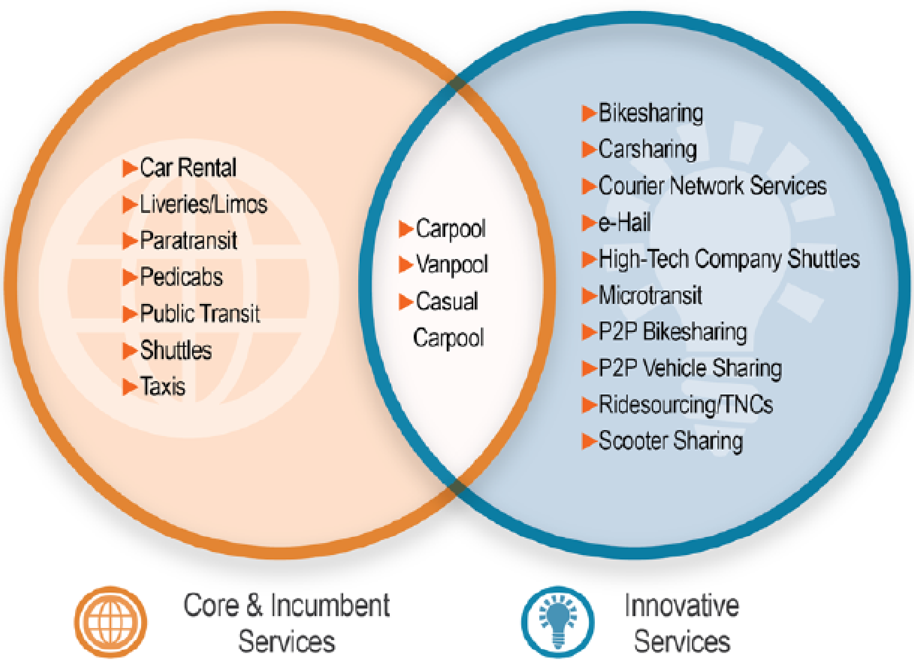
- A reduced reliance on brick-and-mortar retail establishments and a greater prominence of online marketplaces and goods delivery

[3] As described in Collaborative Economy Honeycomb, the six pillars include Space, Transportation, Services, Food, Goods, and Money.

- Heightened environmental awareness about emissions and carbon footprints
- Growth of megaregions as economic centers and transportation corridors
- Changes in land use and shifts toward urbanization and reduced interest in car ownership
- Demographic changes, such as rising life expectancies and an aging population, retiring in place
- Hyper-demand and need for instant gratification driven in part by the demand for immediate results—enabled and magnified by mobile Internet and smartphone apps that can reduce or eliminate the waiting times for goods and services (e.g., taxis, restaurant tables, online shopping, etc.)—that affect most facets of our lives.

Shared Mobility and MOD

One common form of mobility on demand 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. The term shared mobility includes various forms of carsharing, bikesharing, ridesharing (carpooling and vanpooling), and on-demand ride services. It can also include alternative transit services, such as paratransit, shuttles, and private transit services (called microtransit), which can supplement fixed-route bus and rail services (See Figure 6). Shared mobility can also include goods delivery services, such as CNS, that help connect couriers with goods. Shared mobility is having a transformative impact on many global cities by providing innovative mobility services and goods delivery options (Shaheen, Cohen, & Zohdy, 2016).



Source: USDOT Report on Shared Mobility: Current Practices and Guiding Principles, March 2016

Figure 6: Shared Mobility Ecosystem

The *Shared Mobility Primer* (Shaheen, Cohen, & Zohdy, 2016) provides a more detailed discussion on each of the shared modes. Table 2 provides examples of some of the innovative shared mobility services.

Table 2: Examples of Shared Mobility Services

Mode	Description
Ridesourcing/ TNCs	Ridesourcing companies (also known as TNCs and ride-hailing) provide prearranged and on-demand transportation services for compensation, which connect drivers of personal vehicles with passengers. Smartphone mobile applications facilitate booking, ratings (for both drivers and passengers), and electronic payment. Ridesourcing also includes “ridesplitting,” in which customers can choose to split a ride and fare in a ridesourcing vehicle (where available).
Carsharing	With carsharing, individuals have temporary access to a vehicle without the costs and responsibilities of ownership. Individuals typically access vehicles by joining an organization that maintains a fleet of cars and light trucks deployed in lots located within neighborhoods, public transit stations, employment centers, and colleges and universities. Typically, the carsharing operator provides insurance, gasoline, parking, and maintenance. Generally, participants pay a fee each time they use a vehicle.
Ridesharing	Includes carpooling and vanpooling. Typically, employer-based vanpool programs are operated using one of three models: 1) employer owns the vehicle and operates the program; 2) employees own and operate the program with or without employer subsidies; or 3) a third-party contractor owns the vehicles and administers the vanpool program (Business Insurance, 2008).
Microtransit	This is a privately owned and operated shared transportation system that can have fixed routes and schedules, as well as flexible routes and on-demand scheduling. The vehicles generally include vans and buses.
Courier Network Services (CNS)	Courier Network Services (CNS) or flexible goods delivery provide for-hire delivery services for monetary compensation via an online application or platform (such as a website or smartphone app) to connect couriers using their personal vehicles, bicycles, or scooters with goods (e.g., packages, food). Although the business models in this realm are evolving, two general models appear to have emerged—P2P delivery services and paired on-demand passenger ride and courier services.
Bikesharing	In bikesharing systems, users access bicycles on an as-needed basis for one-way (point-to-point) mobility and/or roundtrips. Station-based bikesharing kiosks are typically unattended, concentrated in urban settings, and offer one-way station-based service (bicycles can be returned to any kiosk). Free-floating bikesharing offers users the ability to check out a bicycle and return it to any location within a predefined geographic region. Bikesharing provides a variety of pickup and drop-off locations. Most bikesharing operators cover the costs of bicycle maintenance, storage, and parking. Generally, trips of less than 30 minutes are included within the membership fees. Users join the bikesharing organization on an annual, monthly, daily, or per-trip basis.

Mode	Description
Scooter Sharing	With scooter sharing, users gain the benefits of a private scooter and/or neighborhood electric vehicle (NEV) without the costs and responsibilities of ownership. Individuals typically access scooters and NEVs by joining an organization that maintains a fleet of them at various locations. Typically, the operator provides power/charging or fuel, parking, and maintenance. Generally, participants pay a fee each time they use a scooter/NEV. Trips can be roundtrip, one-way, or both.

Changing Consumption and Delivery Disruption

The role of goods movement is equally important to MOD as passenger movement. In recent years, *consumption choice* has disrupted trip generation and travel behavior. Consumption choice recognizes that digital and goods delivery can serve as substitutes for person trips to access goods and services. A change in a traveler's main trip chain components could be notable, altering the way people experience travel overall, including car ownership and use.

While a growing population will continue to increase their demand for passenger travel, several consumption trends are likely to contribute to a dramatic increase in goods-related trips across the entire transportation network. An overbuilt retail marketplace, changing consumer preferences, the growth of online shopping and service delivery, failing anchor retailers, and rising interest rates are changing the way people consume goods. (SKRISILOFF, 2016), (Peterson, 2017) (Nielsen, 2015) Across the country, strip malls and shopping centers are adjusting to these trends.

Technological innovations, delivery modes, and business models are disrupting how consumers shop, make purchases, and receive goods and services. In the past, a consumer may have purchased the majority of their consumer needs via a trip chain to brick and mortar stores. Today, an increasing array of alternatives is enabling business-to-consumer deliveries.

Seven key innovations in goods delivery are likely to disrupt the traditional trip chain model over the next 10 years:

- **Subscription Delivery Services:** The growth of low-cost, flat-rate delivery subscription services (e.g., Amazon Prime and Shop Runner) are allowing consumers access to on-demand all-you-deliver consumption—a key factor contributing to induced demand.
- **Advanced Algorithms:** Algorithms help merchants and delivery providers optimize the supply and delivery chain from order fulfillment to identifying the least expensive or quickest delivery route.
- **Locker Delivery:** Locker delivery, already widely deployed by the U.S. Postal Service (USPS), allows consumers to order and have items shipped to a self-service locker at home, work, or an alternative pick-up location. Locker delivery can help consumers, merchants, and delivery providers overcome a variety of challenges, such as weekend and off-peak delivery services and enhanced security (versus leaving a package at a door).

- **CNS:** Apps are employed to provide for-hire delivery services for monetary compensation, using an online application or platform (such as a website or smartphone app) to connect couriers using their personal vehicles, bicycles, or scooters with goods (e.g., packages, food).
- **Drones:** A delivery drone is a short-range UAV that can transport small packages, food, or other goods. Some service providers, such as the United Parcel Service (UPS), have experimented with pairing drones and truck-based delivery to improve service delivery.
- **Robotic Delivery:** Like drones, delivery robots offer short-range unmanned ground-based delivery for packages, food, or other goods.
- **Autonomous/Automated Vehicles:** Autonomous/automated and connected vehicles offer another mechanism for future delivery options, both business-to-consumer and P2P.

Emerging courier services have the potential to disrupt and increase the vehicle miles traveled (VMT) from delivery activities. The growth potential of goods delivery VMT is not solely limited to the growth of e-commerce. The increasing availability and affordability of emerging courier services may contribute to a growing array of service providers with their own delivery fleets. In addition to traditional delivery firms, such as UPS, FedEx, DHL, and the USPS, these incumbent services are being augmented by services such as Uber, Postmates, and Instacart. For example, uberEATS is an online meal ordering and delivery platform in which meals are delivered by couriers walking, cycling, or driving for a delivery fee. Postmates couriers operate using bikes, scooters, and cars, delivering groceries, takeout, or other goods from any retailer in a city. They charge different fees (depending on the plan), in addition to a service fee based on the cost of the goods being delivered. Instacart operates similar to Postmates, but it focuses on grocery delivery. Instacart charges vary based on the time given to complete a delivery. In the future, each retailer may offer their own delivery service, increasing the volume and number of delivery vehicles and drones.

Key Takeaways

The key takeaways include:

- MOD includes several core modal and delivery options primarily focused on shared mobility and goods delivery.
- Shared mobility is having a transformative impact on many cities by enhancing transportation accessibility and mobility.
- In recent years, consumption choice has disrupted traditional notions of trip generation and travel behavior patterns. Digital and goods delivery can enhance access to a wide array of goods and services.

Chapter 3. State of the Industry, Business Models, and Partnerships

As discussed in Chapter 1, partnerships can be a key enabler of the MOD ecosystem, which can influence travel behavior and trip generation by affecting important considerations in travel decisions, such as cost, convenience, and security. Some forms of partnerships could also help in realizing the USDOT's multimodal transportation management goals.

This chapter provides an overview on the state of the industry in three sectors—shared mobility, supply chain/goods delivery, and automotive sectors. These sectors are influencing the business models and partnerships within the MOD ecosystem. The chapter also discusses the types of business models and examples of MOD partnerships, as well as includes insights from expert interviews of three use cases (i.e., Bridj, Lyft, and Swiftly), which provide examples of public-private partnerships. The chapter concludes with additional examples from the USDOT's Smart City Challenge that have supported other types of public and private partnerships.

Digital Matching Firms and MOD

Increasingly, consumers and transportation providers are engaging in transactions facilitated by Internet-based platforms—commonly referred to as digital matching firms (Telles, 2016). Airbnb, Uber, Lyft, and Postmates are examples of digital matching firms. According to the Department of Commerce, digital matching firms typically comprise of four key characteristics (Telles, 2016):

1. IT-based systems, typically available via web-based platforms such as mobile apps on Internet-enabled devices, to facilitate P2P transactions.
2. Rely on user-based rating systems for quality control, ensuring a level of trust, virtually, between consumers and service providers.
3. Service providers/operators often have flexibility in deciding their typical working hours.
4. To the extent that tools and assets are necessary to provide a service, digital matching firms rely on the workers using their own.

Digital matching firms are enabling MOD. Some of the benefits of digital matching firms include lower prices to consumers due to decreased transaction and overhead costs, flexible employment opportunities, leverage of excess capacity and underused assets, new forms of consumption, and improved overall customer experience. Some potential challenges can include income instability; less benefits and protections for service providers; lack of training opportunities for service providers (e.g., providers are responsible for their own training); service providers shouldering the capital investment for the service they offer; and privacy and security issues as the firms have access to a substantial amount of data from their consumers (Telles, 2016).

State of the Industry

This section provides a brief overview of shared mobility, supply chains, and the automotive industry sectors. This overview is also helpful to better understand the different business models and partnership types.

Shared Mobility Sector

In North America, the first shared mobility passenger services launched in 1994. Since then, shared mobility passenger and courier services have grown rapidly. Although shared mobility traces its origins to city centers, numerous shared modes continue to expand to markets outside of the city center (a phenomenon discussed in greater detail in Chapter 4).

Some benchmarking data on the shared mobility modes include:

- As of January 2017, there were 21 active carsharing programs in the United States with over 1.4 million members (Shaheen & Cohen, forthcoming 2017). In April 2011, Zipcar, a carsharing company providing short-term (e.g., hourly) vehicle rentals, raised $174 million in its initial public offering, giving it a valuation of $1.2 billion (Ovide, 2011). The Avis Budget Group acquired Zipcar for $500 million in January 2013 (Tsotsis, 2013).
- As of April 2016, there were 32,200 bikes at 3,400 stations across 99 cities (75 IT-based public bikesharing programs) in the United States, serving three user groups: 1) members (users with an annual or monthly membership); 2) casual users (short-term bikesharing users with 1- to 30-day passes); and 3) occasional members (users employ a key fob to pay for a short-term pass) (Meddin, unpublished data).
- In January 2016, various ridesourcing services were available in 175 metropolitan areas across the United States (Cohen & Shaheen, 2016). By December 2014, Uber, the ridesourcing/TNC platform that provides door-to-door for-hire vehicle services, was valued at $41.2 billion (Picchi, 2015). Between mid-2012 through and 2014, the company grew to more than 160,000 drivers (Hall & Krueger, 2015). Just one year later, Uber was valued at $70 billion (Beales, 2016).
- As of July 2011, there were an estimated 638 ridematching services in North America, based on an extensive Internet search. This tally includes online (most have an Internet-based component) and offline carpooling and vanpooling programs. Those located in sparsely populated rural areas, which appeared to have very low use, were excluded. Institutions that have their own ridematching website but employ a common platform were each counted separately. Of the total, 401 were in the United States and 261 were in Canada (24 programs span both countries) (Chan & Shaheen, 2011).
- One app-based courier service, Postmates, was making more than one million deliveries per month, as of April 2016 (Kanaracus, 2016). Under the Postmates Plus program, users can get same-day delivery for $3.99, plus a 9-percent service fee. A subscription plan costing $9.99 per month provides free delivery on all Postmates Plus orders over $25 (Postmates, n.d.)

Supply Chain/Goods Movement Sector

Whether it is a startup (e.g., Instacart, Uber Eats, Postmates, Doordash), an Internet-based retailer (e.g., Amazon), or a supply chain and logistics firm, advancements in courier services (both technologies and service models) are transforming how consumers access goods and services. FedEx, UPS, and DHL are all developing faster delivery services using automation and robotics for both ground-based and aerial vehicles (Shaheen & Cohen, 2017) (Yvkoff, 2017) (Franco, 2016). Innovative technologies and business models to deliver goods and services have the potential for MOD to reimagine goods movement. Table 3 provides a summary of some of the most notable MOD developments in goods movement.

Table 3: MOD Activity in the Goods Movement and Logistics Sector

Supply Chain Company	Activity
FedEx	Internal Developments: Developing AV delivery vans and robots Partnerships: Volvo, Freightliner, and Daimler; developing hybrid AV van and drone delivery system
UPS	Internal Developments: Piloting a drone system that launches from the top of a truck
DHL	Internal Developments: Pilot program testing automated parcel station and aerial delivery drones
Amazon	Internal Developments: Amazon Prime Air drone delivery patent filed for the U.S.

(Shaheen & Cohen, 2017) (Yvkoff, 2017) (Franco, 2016)

Automotive Sector

Interest in MOD by the automotive sector has taken a variety of forms including acquisitions, investments, partnerships, and internal development of technologies and services that were previously not on the radar of automotive original equipment manufacturers (OEMs).

Table 4 summarizes some of the key automotive sector activities within MOD. OEM investments and partnerships with MOD operators, such as Uber and Lyft, are the most common. However, some firms, such as Daimler, have broadened their activities to include multimodal aggregator apps and drones. The diversity and scale of automotive sector activity in MOD is likely to increase in the future, especially as autonomous vehicles become commercially available.

Table 4: MOD Activity in the Automotive Sector

Automotive Company	Activity
Ford	Acquisitions: Chariot (microtransit) Investments: Lyft (ridesourcing) Internal Developments: Ford Smart Mobility LLC; a Ford subsidiary working to design and invest in emerging mobility services
General Motors	Acquisitions: Sidecar (ridesourcing) Investments: Lyft (ridesourcing) Partnerships: Lyft; leases electric Bolt cars to Lyft drivers Internal Developments: Maven (carsharing)
Fiat Chrysler	Partnerships: Google/Waymo (shared automated vehicles); provides Chrysler vans to Waymo as test vehicles

Automotive Company	Activity
Daimler	Acquisitions: car2Go (one-way carsharing), Moovel (multimodal trip aggregator), Hailo (e-Hail taxi app) Partnerships: Matternet (drones)
Volvo	Partnerships: Uber (ridesourcing); joint venture to develop fully autonomous vehicles Partnership: Volvo with its new digital key app paired with Urb-it, a shopping and delivery startup, to deliver goods.
Toyota	Investments: Uber (ridesourcing) Partnerships: Uber; lease vehicles to Uber drivers

(Webb & Whiteaker, 2017) (Ford Media Center, 2016)

These three sectors directly impact passenger and goods movement through a variety of potential impacts on the transportation network (e.g., enhanced goods and mobility access, first-and-last mile connectivity, and last-mile delivery).

Business Models

Understanding common MOD business models can help inform the role of partners and public policy that can support the development, growth, and evolution of MOD. Several MOD business models have evolved to meet the diverse needs of consumers, service providers, and partners. Fundamentally, these business models can be categorized into four groups based on the MOD service provider and consumer: 1) business to consumer (B2C); 2) business to government (B2G); 3) business to business (B2B); and 4) P2P. There can be overlap among business models due to variations in services provided, ownership, administration, and operations. Table 5 provides a description of each business model with examples.

Table 5: MOD Business Models

Business Model	Definition
B2C	Providing individual consumers with access to a business-owned operated transportation services such as a fleet of vehicles, bicycles, scooters, or other modes through memberships, subscriptions, user fees, or a combination of pricing models. Examples: Zipcar Carsharing, Motivate Bikesharing, FedEx, and UPS delivery
B2G	Offering transportation services to a public agency. Pricing may include a fee-for-service contract, per-transaction basis, or some other pricing model. Examples: Government Services Administration (GSA) carsharing pilot program with Enterprise CarShare and Zipcar
B2B	Selling business customers access to transportation services either through a fee-for-service or usage fees. The service is typically offered to employees to complete work-related trips.

Business Model	Definition
	Examples: Corporate and business travel accounts for carsharing and ridesourcing (e.g., Enterprise CarShare, Zipcar, Lyft, Uber), bikesharing for corporate campuses, FedEx and UPS delivery
P2P Mobility Marketplace	Maintaining a marketplace, usually an online platform between individual buyers and sellers of mobility services in exchange for a transaction fee. The platform typically provides insurance and user verification/ratings to facilitate transactions. Examples: Bitlock and Spinlister (Bikesharing), Getaround and Turo (Carsharing), and Scoop (Ridesharing)
P2P Goods Delivery Marketplace	P2P goods delivery services include CNS, apps that provide for-hire delivery services for monetary compensation using an online application or platform (such as a website or smartphone app) to connect couriers using their personal vehicles, bicycles, or scooters with goods (e.g., packages, food). These apps can be subdivided into two types: • P2P Delivery Services are apps that enable private drivers to collect a fee for delivering cargo using their private automobiles (e.g., Roadie). • Paired On-Demand Courier Services are apps that allow for-hire ride services to also conduct package deliveries (e.g., UberEATS).

(Shaheen, Cohen, & Zohdy, 2016)

The government, through supportive and unsupportive public policies, can influence the success and growth of MOD (e.g., tax incentives or disincentives, special incentives or in-kind support for non-profit operators). Although each of these business models can include a variety of government support, the most common type of support is rights-of-way, grants, and direct subsidies of business-to-consumer and business-to-government service models. The role of government can also impact potential risk to public and private partners through vicarious liability. Vicarious liability refers to a situation when a third-party (e.g., a MOD partner or public agency) is held responsible for the actions or omissions of another (e.g., a MOD vendor, operator, or user). In an MOD context, depending on legal agreements, limits of liability, and insurance, a public agency could be liable for the actions of a vendor or user if it can be shown that a particular action took place because a public agency took (or failed to take) a particular action (e.g., enforcing a safety inspections clause in a vendor agreement).

MOD Partnership Types

Emerging innovative transportation services can confront a wide array of policy, financial, and marketing outreach challenges, among others. Identifying MOD partners can aid the growth and mainstreaming of MOD operators and service models. MOD partners come from public, private, and institutional sectors, providing a range of accommodations that can benefit MOD operators.

Local and regional governments are the most common public partners of MOD service providers because of their role in transportation planning, public transportation, and parking policy among others. Employers, businesses, and educational institutions are also common MOD partners because of their roles in transportation demand management. Developers and public transit agencies are other examples of common partners with MOD because of their shared goals to reduce parking and support transit-oriented development.

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. They can also provide support in the establishment of standards, data sharing, inclusion of MOD into zoning and other public policies, risk sharing, and marketing. As such, public-private partnerships can play a key role in addressing several policy challenges that could help to evolve MOD to maximize its social and environmental benefits (Shaheen, Cohen, & Zohdy, 2016). Table 6 provides a more detailed list of common partners, types of support, and examples.

Table 6: MOD Partnerships

Partners	Types of Support	Support Examples
State Agencies and Regulatory Bodies	Statewide Standards	California Public Utilities Commission (CPUC) provides a legal definition and statewide requirements for ridesourcing companies. State departments of insurance and motor vehicles may provide similar legal definitions and requirements. Unifying and simplifying regulatory authority under a single state agency is one way that state agencies can support the growth of MOD.
City and Regional Governments and Public Agencies	Data Sharing	The City of Los Angeles shares rights-of-way capacity and incident data with MOD apps.
	Managing Rights-of-Way	A number of cities have on-street carsharing parking permit policies for roundtrip and one-way service models (e.g., San Francisco, Seattle).
	Inclusion of MOD as a TDM Measure	Santa Monica, CA, requires developments seeking a variance to include TDM measures. TDM measures could include incorporating shared modes, carpooling parking, bicycle lockers, or workplace showers (to encourage cycling).
	Tax Reform	Multnomah County, OR, exempts carsharing from rental car taxes.
	Facilitating Stakeholder and Community Involvement	The New York City Department of Transportation (NYCDOT) conducted over 100 public meetings in multiple languages along with virtual engagement as part of the city's bikesharing planning process.
	Risk Sharing	Arlington County Community Services (ACCS) partnered with Flexcar and Zipcar to add additional vehicles with a risk-sharing partnership. ACCS partnered using a "subtraction model" in which the MOD operator valued the monthly cost of providing service and subtracts monthly revenue from that collected value and bills the shortfall to the risk partner. This particular subsidy was discontinued in May 2005, when vehicle revenue exceeded operational costs of providing service.

Partners	Types of Support	Support Examples
Public Transit Operators	Data Sharing	The Regional Transportation District in Denver shares real-time public transit information vis-à-vis an Application Programming Interface (API) with multimodal vendors and the public through the GoDenver app.
	MOD Linking	Dallas Area Rapid Transit (DART) provides a hyperlink to Uber from its public transit app. Public transit agencies can also incorporate APIs to offer enhanced features (e.g., greater integration), rather than simply hyperlinking to MOD operators.
	Transit Fare Integration	Chicago Transit Authority and Divvy will test an integrated fare card as part of its MOD Sandbox project.
	Designated Parking or Loading Space	Bay Area Rapid Transit (BART) provides designated carsharing spaces at select BART station parking lots.
	MOD Fare Subsidy	Pinellas Suncoast Transit Agency provides subsidies to paratransit and ridesourcing operators when providing service to low-income users and people with disabilities.
	Paratransit	A lot of public transit agencies subcontract to third-party vendors to provide paratransit services (e.g., Pinellas Suncoast Transit Agency).
Employers and Businesses	Internal Marketing	*Seattle Times* provides internal marketing support for carsharing.
	Use of MOD for Business Travel	Swedish Medical Center in Seattle provides carsharing memberships to employees for business-related trips.
Developers and Property Managers	Incorporating MOD into Facility Design	Developers of the Gaia building in Berkeley, CA, designated carsharing spaces in the parking garage.
	MOD Membership Subsidies	Condominium developers in Vancouver, Canada, offer carsharing membership as an amenity to residents.
	Risk Sharing	Developers can employ risk-sharing partnerships similar to the ACCS model noted above of subtracting the cost of MOD service from monthly revenue and billing any shortfall to the risk partner (e.g., developer/property manager).
	Marketing	Equity Office Properties in Seattle promotes carsharing to building tenants.
Universities	Marketing to Students	The University of Pennsylvania includes information about carsharing in welcome packets sent to students.
	Designated Parking	MIT and Zipcar have a partnership to provide discounted carsharing membership (including a designated parking space) to students and faculty.

(Cohen & Shaheen, 2016), (Shaheen, Cohen, & Zohdy, 2016), (Millard-Ball, ter Schure, Fox, Burkhardt, & Murray, 2005), (Wilonsky, 2015), TSRC unpublished research

Benefits of MOD for Partners

Supporting MOD may have potential social, environmental, transportation, economic, and other benefits for partner organizations, such as reducing parking demand, decreasing partner costs, and achieving environmental goals (e.g., reduced greenhouse gas emissions). Potential benefits to partners could include:

- Parking mitigation
- Congestion mitigation
- Improved accessibility (i.e., more equitability) and mobility
- Increased vehicle and goods access, particularly to carless households
- Increased modal and multimodal options
- Bridged gaps in the transportation network (e.g., underserved areas, first-and-last mile connections)
- Improved air quality
- Reduced greenhouse gas emissions
- Increased public transit ridership
- Cost savings (to system users and public agencies)
- Customer or resident amenity at destinations
- Increased economic activity near MOD services and modal nodes
- Increased efficiency of existing fleets (e.g., motor pools and public transit fleets)
- Opportunities for discounts, joint marketing, education, and outreach
- Fare integration with other modes
- Tax savings for property managers and employers
- Champions and customers of shared modes (e.g., employers, institutions, and public agencies)
- Reinforced image of sustainability and corporate stewardship.

Numerous public agencies have partnered with MOD service providers to further environmental goals, such as reduced VMT and emissions, lower car ownership, reduced SOV travel, reduced parking demand, and increased access and mobility. Providing access to MOD may be a way to reduce parking demand, which can in turn reduce development and administrative costs as well as contribute to larger travel behavior shifts. In addition to cost savings from foregone parking construction, employers, developers, and institutions (e.g., universities) can also leverage MOD as an affordable alternative to directly providing transportation amenities to employees, residents, and students. Some public transit agencies, such as the Pinellas Suncoast Transit Agency in St. Petersburg, Florida, are also experimenting with supporting MOD to reduce the cost of service provision for low-ridership corridors and late-night periods. Ultimately, the goal of partnering with MOD operators is to harness the potential positive impacts (e.g., accessibility, reduced travel costs), reduce SOV dependency, and shift travel behavior toward modes that help achieve air quality and climate goals.

While most partnerships between public agencies and MOD providers are informal in nature (e.g., joint marketing), increasingly, public agencies are entering more formalized partnerships through requests for proposals, memoranda of understanding (MOUs), and other processes. For example, in the City of Alexandria, Virginia, the ridesharing coordinator was introduced to carsharing at a conference and became proactive in reaching out to prospective operators in the early 2000s. In some cases, public agencies have launched their MOD services, such as bikesharing (e.g., NYCDOT) and carsharing (e.g., Scoot Carsharing by Kitsap Transit Authority).

In other cases, partnerships can also yield regulatory relief or tax incentives. Since the early 2000s, Washington State has provided TDM trip-reduction credits to employers and property managers providing financial incentives for non-SOV travel, such as ridesharing, carsharing, and public transportation. Property managers and employers taking this credit may claim a tax credit up to 50 percent of the incentive paid either to or on behalf of the employee or tenant.

MOD Use Case Studies on Public-Private Partnerships

As part of this concept of operations, four expert interviews with public-private partnerships were conducted between April and October 2016. These interviews included:

- Bridj[4] (no longer operational in the microtransit market, although several other microtransit operators are currently expanding in the United States) partnership Kansas City Area Transportation Authority (KCATA)
- Lyft initiatives with public agencies
- Swiftly App (now with a new business model) and public-private data sharing partnerships.

Three of these case studies (Bridj, Lyft, and Swiftly) highlighted various opportunities for public and private transit operator partnerships to expand service availability, improve operational efficiency, and reduce costs. The case studies also highlighted the potential opportunities for app-based services and multimodal aggregators. Multimodal aggregators typically aid in the commodification of transportation services by allowing users to compare modal options and costs, thereby bridging information gaps and making multimodal travel and public transit more convenient (aligned with the USDOT vision of multimodal transportation management operation). Both Bridj and Lyft emphasized partnerships that could enable public transit agencies to save money by integrating private-sector solutions, such as right-sizing and dispatch operations for both public transit and paratransit service.

The **Bridj** and KCATA partnership highlighted opportunities for public and private transit operators to partner and implement technological innovations, such as on-demand scheduling and flexible routing. In March 2016, Bridj commenced a pilot program in partnership with KCATA to offer flexible transit services. KCATA operates the program with KCATA drivers and 10 KCATA 14-passenger vans. In many sections of the Bridj Kansas City service area, there was no pre-existing public transportation service. Bridj viewed its service as an opportunity for public transportation agencies to partner on an innovative mobility strategy. Historically, bus public transit services have had operational inefficiencies, such as lower ridership (compared to vehicle size), long headways (time between buses), low fare-box recovery, and higher operating costs per hour. Bridj believed that microtransit may be able to help public transit agencies save money by providing lower-cost options in lower density areas or with new routes that may not have an established ridership.

Lyft is a for-hire ridesourcing/TNC operator offering three core services: 1) Lyft, 2) Lyft Plus, and 3) Lyft Line. The Lyft interview highlighted opportunities to leverage data and APIs to enable public transit agencies to “smart dispatch” right-sized vehicles for passengers with special needs. Lyft stated that they

[4] Bridj is defunct as of April 2017. Bridj was one of several microtransit operators and was unable to procure additional investment. Chariot and Via are examples of current operators that are expanding across the United States.

are exploring an array of public transit partnerships that could subsidize Lyft rides for certain populations or locations in the future, reducing the cost of Lyft services and making it more accessible to underserved communities. Initially, the lack of legal definitions adversely impacted the ability for public transit to partner with ridesourcing. According to Lyft, legal legitimacy plays a key role (i.e., ridesourcing has to be legalized before public agencies can enter into formal partnerships). Lyft views the potential for complementarity with public transit, particularly with first-and-last mile connections to fixed (typically regional) rail networks. Lyft views reducing SOV travel to rail transit as a core opportunity due to the parking challenges commonly associated with rail transit, such as the cost and availability of parking. In the words of the Lyft expert interviewed: “our customers are leading us in this direction by using our product as a first-and-last mile connection.”

The interview also highlighted a Lyft partnership with GoLA and Xerox. Xerox app users can hail a Lyft ride or book a Zipcar through its app vis-à-vis third-party API integration. Xerox’s interface takes a user’s destination and desired arrival time to develop an algorithmic recommendation of different routes and modes available, allowing users to select a route based on departure time, price, and environmental impact (Xerox, 2016). This level of integration allows users to employ their public transit payment account to pay for a Lyft ride (or other mode) on a third-party platform without being required to have a Lyft account and a saved credit card.

Swiftly App is a multimodal aggregator founded in 2014. Swiftly is a technology platform offering three core services: 1) Swiftly Mobile, a multimodal trip aggregator for end-users; 2) Swiftly Transitime; and 3) Swiftly Analytics. The latter two services help public agencies and cities improve the operational efficiency of public transportation by providing more accurate transit departure and arrival information to mobility consumers and providing a transit management dashboard for public transit agencies. The interview focused on the end-user Swiftly Mobile app. The goal of the Swiftly Mobile app is to provide users with options for getting between origins and destinations primarily using non-motorized modes by leveraging high-quality, real-time information services to improve public transit reliability.

All three of these use cases identified scenarios where public-private partnership can address some of the challenges of public transit.

Examples of MOD in the Smart Cities Challenge

In December 2015, the USDOT launched the Smart Cities Challenge initiative to demonstrate the potential of integrated data, ITS, and applications to improve safety, enhance mobility, and address climate change. The USDOT committed $40 million (and up to $10 million from Vulcan Inc.) in ITS research funding as part of this process. The funding was intended to stimulate partnerships among the public sector, major institutions, and 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 among federal, state, and local governments with the private sector to move forward the core vision of MOD (i.e., using technology and data to help people and goods move more quickly, safely, efficiently, and economically).The vision of the Smart City Challenge was to demonstrate and evaluate an integrated approach to improving surface transportation performance within a city and integrate surface transportation technologies with other aspects of public administration, such as first response, public services, and energy.

The Smart City Challenge produced seven finalists: Austin, Columbus, Denver, Kansas City, Pittsburgh, Portland, and San Francisco. The finalists’ public-private-partnership-driven proposals included a range of technological and administrative innovations to advance MOD implementation in urban areas.

The Smart City Challenge represents the first step in recognizing how strategic partnerships between public sector agencies, significant institutions, and private sector technology providers (see Table 7) can make U.S. cities more livable, efficient, environmentally sustainable, and equitable. All the Smart City Challenge finalists also identified opportunities for leveraging technology to improve key quality of life metrics that extend beyond transportation. Some of these included initiatives to bridge the digital divide, fight crime, reduce unemployment, and increase affordable housing. In the future, the role of transportation planners will evolve and more frequently require an understanding of how smart city transportation investments can interface, impact, and be impacted by other aspects of urban planning and policy.

In summary, the variety of deployment plans, use cases, and policies employed within the seven final Smart City Challenge proposals shows how local values and geographic factors can influence the diverse application of similar technologies. How effective these proposals are at addressing stated goals remains to be seen. Table 8 shows the MOD features that were included in the proposals.

Table 7: Smart City Partnerships

Cities	Partnerships Types
Austin	City DOT, Municipal Energy Utility, Regional Mobility Authority, Think Tank, State DOT, Academic
Columbus	City DOT, Philanthropy, Healthcare, Business, Academic
Denver	City DOT, State DOT, State of Colorado, Regional Transportation District, Academic, Non-profit, Automakers, Telecom, Think Tank
Kansas City	City DOT, Transit agency, State DOT, Airport, Non-profit, Technology firms, Academic
Pittsburgh	City DOT, Universities, Non-profit, Business
Portland	City DOT, County, Port Authority, Transit Agency, State DOT, Faith, Equity champions, Academic, Business
San Francisco	City DOT, Academic, Equity, Environmental, Business

Table 8: Smart City Proposals: MOD Vision Concepts
(from public sources at the time of developing the report)

Finalist Cities	Deployment Focus	MOD Vision	MOD Pilot Projects
Austin	• Multimodal Hubs • Arterial Corridor • Highway Corridor	• *Multimodal Smart Stations*, highway corridor ITS applications, and a complete-street electric bus rapid transit (BRT) arterial corridor between the airport and downtown • *Smart Ambassadors* -- people trained specifically to ensure access of proposed services to vulnerable users including older adults, low-income individuals, and non-native English speakers	**Planned:** • Multimodal smart stations • Smart ambassadors • First- and last-mile access to employment, healthcare, and public transit • Automated downtown circulator and airport shuttle

Finalist Cities	Deployment Focus	MOD Vision	MOD Pilot Projects
Columbus	• Multimodal Hubs • Highway Corridor • Arterial Corridor	• Typology of districts—residential, downtown, commercial, and logistics—connected by BRT corridors with transit signal priority, a dedicated short-range communication (DSRC) equipped arterial corridor • Dedicated trucking corridor between the commercial and logistics districts	**Planned:** • Connected Automated Vehicle Corridor • Automated downtown circulator shuttle • Multimodal hubs
Denver	• WiFi Kiosks (arterial corridor and citywide) • Arterial Corridor	• Mobility on Demand Enterprise (MODE) WiFi kiosks along the regional rail network and busy bus corridors that connect un-phoned residents with app-based mobility options • Conversion of municipal fleets and busses to electric vehicles • Deployment of connected and automated vehicles along busy bus corridors	**Existing:** • Centennial ridesourcing/TNC first- and last-mile access pilot • GODenver Mobility Marketplace to share data and find matches between supply and demand **Planned:** • Connected automated corridor • Subsidized ridesourcing/TNC first- and last-mile access • Ridesourcing/TNC driver car rental pilot
Kansas City	• District • Arterial Corridor • Highway Corridor • Intermodal Freight Parks	• WiFi kiosks along an existing streetcar corridor • “Smart highway” corridor ITS applications • Automated vehicle shuttle between downtown and airport • Connected street lighting and Internet access along an arterial corridor • Freight connected vehicle applications at an intermodal freight park	**Existing:** • Bridj microtransit pilot • Public WiFi kiosks **Planned:** • Connected automated BRT corridor between low-income neighborhoods and job centers • Semi-automated vehicle corridor between the airport and downtown
Pittsburgh	• Micro-grid District • Arterial Corridor	• Micro-electric-grid districts connected by “Smart Spine” arterial corridors with adaptive traffic signal control to reduce congestion and air pollution	**Existing:** • Dynamic parking pricing connected vehicle network

Finalist Cities	Deployment Focus	MOD Vision	MOD Pilot Projects
		• Electric Avenue (a smart corridor) will pilot automated electric vehicle (EV) shuttles • Dynamic parking pricing along its Smart Spines	**Planned:** • Dynamic parking management
Portland	• WiFi Kiosks (public transit stops) • Arterial Transit Corridor • Connected Vehicle Corridor Zone • Automated Vehicle Corridor Zone	• Specific ITS applications in zones radiating from a central arterial corridor • Central Corridor: Air quality sensors, smart public transit stations, and DSRC roadside units • Inner Zone: Connected vehicles for urban delivery • Outer Zone: Automated vehicle neighborhood shuttle pilot to connect residents with the high-frequency transit in the central corridor	**Existing:** • General Transit Feed Specification Real Time **Planned:** • Subsidized ridesourcing/TNC trips for people with disabilities • Connected fleets and vehicles • Open Data Cloud • Automated vehicle first- and last-mile connection
San Francisco	• Multimodal Hub • District • Arterial Corridor • Highway Corridor • Citywide • Regional	• Project scales of neighborhood, city, and region • Neighborhood: Automated vehicle first-and-last-mile shuttles connecting outer neighborhoods to public transit • City: Late-night employee shuttles connecting late-night service job centers downtown with neighborhoods • Region: Carpool pilot with dedicated carpooling lanes on highways and reserved curb space near job centers downtown	**Existing:** • Dynamic Parking Pricing **Planned:** • Shared van shuttle • Shared mobility hubs with EV charging, Wi-Fi, transit, and bikeshare • Automated vehicle first- and last-mile connection • Regional high-occupancy-vehicle lanes • Carpool pick-up curbs

Key Takeaways

The key takeaways include:

- Several business models (B2C, B2G, B2B, P2P) have evolved to meet the diverse needs of consumers, service providers, and partners. Supporting MOD has numerous potential benefits for partner organizations (public or private), such as reducing parking demand, decreasing partner costs, and achieving environmental goals. Ultimately, the goal of partnering with MOD operators is to harness positive impacts (e.g., increased accessibility, reduced travel costs), reduce SOV travel, and shift travel behavior in a way that helps reduce congestion and improve air quality.
- Public agencies should explore opportunities for public and private collaboration. Public-private partnerships can support a more multimodal transportation network that can enhance accessibility, livability, and quality of life.

Chapter 4. Built Environments

This chapter discusses the various potential applications of MOD in different built environments. It describes the categories of travel constraints, which directly affect and are affected by the built environment; each built environment type; and examples of constraint types and MOD solutions. Although the MOD ecosystem focuses on the entire supply chain for personal travel and goods movement, this chapter focuses primarily on passenger mobility services.

While MOD has typically emphasized higher-density and mixed-use built environments, increasingly, MOD is expanding into lower density and more suburban locations. MOD also has the potential to service exurban and rural use cases. For example, carsharing has become increasingly available in many small- and medium-sized college towns.

The variety of urban environments create several opportunities and challenges for MOD deployment. Some of the common use cases across all built environments include daily commuting and business trips, goods movement, and trips for people with special needs or disabilities. Investigating these scenarios for different land uses could better inform potential solutions to address the constraints and affect future building and land developments.

Primary Travel Constraint Types

Many travelers may experience transportation constraints throughout the day as they go through the trip chain. The impact of these constraints may be associated with spatial, temporal, economic, physiological, and social barriers. Table 9 provides a summary of how the **STEPS** (Spatial, Temporal, Economic, Physiological, and Social) framework applies to MOD. This framework was developed by Shaheen et al., 2017, as part of an effort funded by the FHWA Office of Transportation Policy Studies (Shaheen et al., forthcoming).

While there are numerous approaches to address these constraints, including building denser, mixed-use communities or expanding the coverage of existing public transit systems, shared mobility may provide some advantages. For instance, shared mobility may provide lower cost, quicker deployment, flexibility, and enhanced convenience in contrast to longer-term infrastructure and development project approaches (e.g., developing a new rail line). These constraints are closely tied to the type of land use and urbanization that are highlighted later in this chapter.

As noted in Table 9, each of these constraints represent unique MOD opportunities and challenges that require different responses from multimodal transportation operation management DSS to better manage the ecosystem. For example, for the temporal barriers, the best decision/response may be to use ridesourcing services for late nights, instead of extending the public transit schedule.

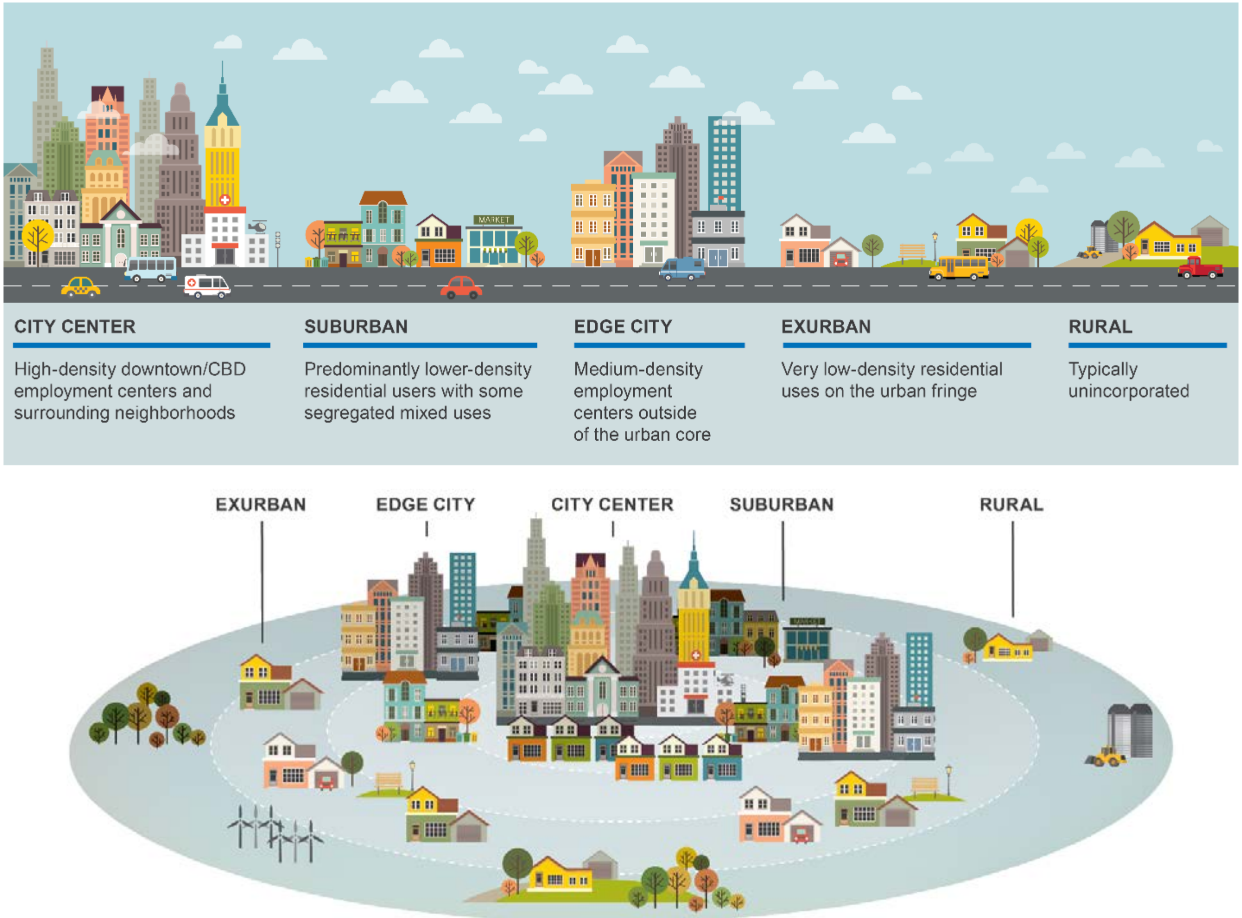
Table 9: STEPS Framework Applied to MOD

Constraint Type	Definition	MOD Opportunities	MOD Challenges
Spatial	Spatial factors that compromise daily travel needs (e.g., excessively long distances between destinations, lack of public transit within walking distance). Spatial factors can also include distance from community resources such as grocery stores, retail centers, educational institutions, parks, and others.	• Public transit operators and ridesourcing/TNC first- and last-mile partnerships • Microtransit for lower-density areas • First-and-last mile goods and digital delivery to areas lacking community resources (e.g., goods delivery, remote healthcare, online learning)	• Higher operating costs (passenger movement and goods delivery) in lower-density exurban and rural settings • Limited curb space for increasing variety of mobility services • Bandwidth limitations that may limit or inhibit MOD passenger and goods ordering capabilities.
Temporal	Travel time barriers that inhibit a user from completing time-sensitive trips, such as arriving to work (e.g., public transit reliability issues, limited operating hours, traffic congestion)	• Dynamic microtransit • Late-night ridesourcing/TNC and shuttle services • Commuter carpooling services	• Wait-time and travel-time volatility on congested roadways • Unpredictable wait times due to supply fluctuations
Economic	Direct costs (e.g., fares, tolls, vehicle ownership, and delivery costs) and indirect costs (e.g., smartphone, Internet, credit card access) that create economic hardship or preclude users from completing basic travel or receiving goods and services.	• MOD subsidies for low-income users • Multiple payment options for shared mobility services • Multimodal hubs with Wi-Fi access • Free delivery and low-cost flat-rate subscription delivery services (e.g., Amazon Prime, ShopRunner etc.)	• Credit/Debit Card payment • High cost for longer distance and peak-demand trips • Maintaining affordability, while providing livable wages • High one-time annual costs of delivery subscription services.

Constraint Type	Definition	MOD Opportunities	MOD Challenges
Physiological	Physical and cognitive limitations that make using standard transportation modes difficult or impossible (e.g., infants, older adults, and people with disabilities)	• Older adult-focused MOD services • Voice activated mobility app features • Goods delivery and digital delivery services that eliminate the need for a trip (e.g., substituting goods delivery for people movement).	• Maintaining legacy technology access • Ensuring adequate driver training
Social	Social, cultural, safety, and language barriers that inhibit a user's comfort with using transportation (e.g., neighborhood crime, poorly targeted marketing, lack of multi-language information)	• Ridesourcing/TNC app interface that minimizes sociodemographic profiling • Targeted outreach to low-income and minorities • Website and app information in user's native language	• Attracting marginalized groups • Driver prejudice against riders • Providing security at un-manned vehicle stations

MOD in Different Built Environments

Between 1800 and 2000, the U.S. population grew 6,150 percent from 4 million to more than 250 million. During this same period, the nation's land area grew 270 percent from 1 million to 3.7 million square miles. Over this period, the percentage of Americans living in urban areas increased from less than 5 percent to nearly 80 percent. Despite this shift from rural to urban areas, most of the post-World War II growth has occurred in suburbs outside of central cities. Over the past 30 years, a number of these suburbs have urbanized into edge cities with employment centers and densities more emblematic of city centers and street patterns similar to suburbs. The variety of urbanization patterns pose several opportunities for MOD deployment.



Source: USDOT, August 2017

Figure 7: Five Common Built Environments in the U.S.

While MOD is most often associated with dense urban areas, there are many possible applications in different development contexts between the city center and rural areas. While development between dense central business districts (CBDs) and sparsely populated rural towns exists on a spectrum, this report focuses on five common development typologies along the spectrum including:

- ***City Center:*** A development framework with the highest concentration of jobs comprised of CBDs and surrounding neighborhoods.
- ***Suburban:*** A built environment characterized by high-levels of low-density residential uses with fewer jobs than residences.
- ***Edge City:*** An urbanization pattern presenting some features of city center employment mixed with suburban form. Edge cities tend to have large concentrations of office and retail space often paired with multi-family residences.
- ***Exurban:*** Low-density residential development within the commute shed of a larger and denser urbanized area.
- ***Rural:*** The lowest density development pattern characterized by low-density light industrial, agricultural, and other resource-based employment.

Table 10: Built Environment Characteristics Rank (5 = highest, 1 = lowest)

Factors	City Center	Edge City	Suburb	Exurb	Rural
Population Density	5	4	3	2	1
Public Transit Availability	5	4	3	2	1
Transportation Options	5	4	3	2	1
Land Affordability	1	2	3	4	5
Parking Availability	1	2	3	4	5
Travel Speed	1	2	3	4	5

City Center MOD

The city center built environment has the highest development density and jobs-to-housing ratios. This creates a high density of trip origins and destinations with high travel demand throughout the day, often straining the capacity of automobile roadways and parking. The housing-jobs imbalance between the city center and suburbs creates traffic flow and congestion challenges into the CBD in the morning and out of the CBD in the evening (in most metropolitan regions). The densest city centers may also experience public transit congestion when demand approaches or exceeds supply. City centers often provide the most diverse transportation options.

The city center scenario includes the following elements:

- More than 15 million to 20 million square feet of leasable office space
- More than 3 million square feet of leasable retail space
- More jobs than dwelling units
- High-density multi-family residential (typically in excess of 50 dwelling units per acre).

Source: Metropolitan Council of Governments

Figure 8: 59 Dwelling Units Per Acre

City Center examples include the downtowns of San Francisco; Washington, DC; Los Angeles; and Atlanta.

In the city center urban framework, MOD offers the potential to replace fixed vehicle ownership costs with variable costs by offering more mobility choices. Several shared modes have been demonstrated to reduce car ownership and reduce VMT/emissions (e.g., carsharing, bikesharing, traditional ridesharing). For example:

- MOD could reduce demand for private automobiles and single-occupant travel, particularly in city centers, by providing first-and-last mile connections to public transportation, more public transport option, and a more convenient multimodal experience through trip planning apps and integrated fare payment options
- Parking mitigation when MOD reduces VMT, vehicle trips, and/or vehicle ownership (e.g., carsharing)
- MOD can offer short-distance and medium-distance transportation alternatives to private vehicle use through services, such as bikesharing and scooter sharing
- MOD can help mitigate congestion and emissions when MOD modes reduce VMT, vehicle trips, vehicle ownership, or emissions (e.g., carsharing and bikesharing)
- MOD may increase affordability of transportation (by providing additional modal options at a variety of price points); housing (through reduced parking infrastructure, if savings are passed on to consumers); and eliminating trips (through goods and service delivery options).

In this urban context, common use cases may include first-and-last-mile connections to public transportation, urban goods movement (e.g., CNS); daily commuting and other business trips; school trips; and trips for people with special needs, such as disabled users, caregivers, medical trips; etc.

Additional use cases may include mobility for special circumstances, including special events and disaster response (e.g., evacuation).

MOD may also mitigate public transit congestion during peak periods and offer late night travel when public transit systems have reduced service. The density of trip origins and destinations makes pooled services, such as pooled ridesourcing/TNCs (e.g., UberPOOL, Lyft Line) and microtransit (e.g., Chariot, Via) an affordable option for users willing to share a ride.

Table 11: Examples of City Center MOD Use Cases

Constraint Type	Constraint	MOD Solutions
Spatial	Limited parking for special events; Limited on-street space for loading zones and parking	Ridesourcing/TNCs, microtransit, e-Valet, e-Parking, e-Hail; CNS
Temporal	Fewer off-peak public transit options for late-night workers	Late-night employee shuttle
Economic	High cost of parking and car ownership	Carsharing, ridesourcing/TNCs, ridesharing apps, multimodal trip planning apps
Physiological	Difficulty navigating public transit in a wheelchair	Accessible ridesourcing service, paratransit, microtransit
Social	Lack of services in user's native language	MOD apps in user's native language

Suburban MOD

Historic suburbanization patterns tend to exhibit lower development intensities and population densities than the city center, which typically reflects a jobs-housing imbalance. This results in travel demand that is more peaked during the morning and evening commute hours away from the suburb toward job centers. The land use pattern is dominated by single-family detached dwelling units and "garden-style" low-density multi-family residences segregated from commercial uses along non-grid hierarchical street networks, making alternatives to driving more difficult. The auto is well served most of the time with supply constraints at peak demand times. While some older suburbs may have been originally built around rail transit (e.g., streetcars), today, public transit generally has limited geographic coverage and operates less frequently than in city centers. Public transit in the suburban context is typically used by those who have limited transportation options (e.g., low-income, people with disabilities, youth, and older adults).

The suburban scenario includes the following elements:

- Between 4 to 10 dwelling units per acre
- Single family detached dwelling units or "garden style" low-density multi-family residences
- Zoning separates residential and commercial uses, with commercial uses concentrated in malls surrounded by parking.

Source: Metropolitan Council of Governments

Figure 9: Five Dwelling Units Per Acre

Source: Metropolitan Council of Governments

Figure 10: Seven Dwelling Units Per Acre

Some classic suburban examples include Sandy Springs, Georgia (Atlanta, metro); Danville, California (San Francisco, metro); and Calabasas, California (Los Angeles, metro).

Common suburban use cases may include first-and-last-mile connections to public transportation; daily commuting and other business trips; school trips; trips for low-income and carless households; and trips for people with special needs, such as people with disabilities, caregivers, those needing medical trips, etc.

Table 12: Examples of Suburban MOD Use Cases

Constraint Type	Constraint	MOD Solutions
Spatial	Limited school drop-off space	Parent ridesharing apps, youth specific ridesourcing apps (e.g., HopSkipDrive)
Temporal	Infrequent public transit service	Microtransit, CNS goods delivery
Economic	Lack of affordable alternatives to auto ownership	Carsharing, ridesharing app; microtransit, ridesourcing/TNC and volunteer services (where ridership and/or densities may not be high enough to justify a fixed-route public transit service); innovative payment operations that expand the resources available for MOD, such as trading cars for rides, volunteer credits, and co-payments from merchants and healthcare providers (e.g., ITN*America*)
Physiological	Lack of youth/older adult mobility alternatives to the automobile	Youth-specific ridesourcing; older-adult-specific services
Social	Social stigma for suburban bus users	Carsharing, ridesourcing, targeted marketing toward suburban users

Suburban MOD provides the following potential benefits via eliminating the fixed cost of car ownership and adding more transportation choices. Through shared mobility, MOD also provides more options for users that could not access public transportation as easily.

1) Enhanced accessibility and convenience by providing additional modal alternatives to private vehicle ownership
2) Reduced travel times when MOD is faster than driving and parking a private vehicle
3) Reduced parking demand when MOD modes have been shown to reduce vehicle trips or vehicle ownership
4) Increased social and economic inclusion by providing carless and low-income households additional modal options in a built environment that historically has required private vehicle ownership for accessibility.

One of the biggest challenges in the suburban built environment is competition with personal (and more specifically single occupant) vehicles. Moreover, ridesourcing/TNCs can be less affordable in the suburbs due to a variety of factors, such as fewer drivers, longer trip lengths, and a smaller customer base that can limit or prohibit discounted pooled rides, such as UberPOOL and Lyft Line.

Improving real-time data services and partnering with the private sector, creating open platforms (e.g., data sharing and data commons), and encouraging technological integration and interoperability between the public and private sector could be key opportunity areas for the advancement of suburban MOD.

Edge City MOD

The edge city framework presents some features of city centers mixed with suburban form. Edge cities tend to have large concentrations of office and retail space with a jobs-housing ratio similar to the city center, resulting in work trips toward the edge city in the morning and away from it in the evening

(Garreau, 1992). Edge cities do not exist in isolation, but they compete directly with existing city centers within their metropolitan areas. Apart from being employment centers, the edge city development density, street network, and auto-orientation has much more in common with residential suburbs than city centers.

The edge city concept was first defined by (Garreau, 1992) as a place having:

- At least 5 million square feet of leasable office space
- At least 600,000 square feet of leasable retail space
- Medium-density multi-family residences (typically 10 to 50 dwelling units per acre)
- More jobs than bedrooms
- Public perception as one place
- Non-existent prior to 1960.

Source: Metropolitan Council of Governments

Figure 11: 32 Dwelling Units Per Acre

Examples of edge cities include Irvine, California (Los Angeles Metro); Tyson's Corner, Virginia (Washington DC Metro); Buckhead, Georgia (Atlanta Metro); and Walnut Creek, California (San Francisco Metro).

Table 13: Examples of Edge City Use Cases

Constraint Type	Constraint	MOD Solutions
Spatial	First-mile-last-mile public transit connection (e.g., connections from transit to large employment centers)	Bikesharing, microtransit, ridesourcing/TNC-public transit partnerships
Temporal	Commute hour congestion	Ridesharing apps, microtransit, carpooling rights-of-way incentives (e.g., parking and toll discounts, high-occupancy vehicle (HOV) lanes)
Economic	Lack of affordable alternatives to auto ownership	Carsharing, innovative payment programs and volunteer services; co-payments from sponsors, merchants, healthcare providers

Constraint Type	Constraint	MOD Solutions
Physiological	Lack of accessible public transit services	Microtransit, paratransit, ridesourcing/TNCs, CNS
Social	Negative perceptions of public transit	Microtransit, ridesourcing/TNCs

Potential benefits enabled through edge city MOD are very similar to suburban MOD and include:

1) Enhanced accessibility and convenience by providing additional modal alternatives to private vehicle ownership
2) Reduced travel times when MOD is faster than driving and parking a private vehicle
3) Reduced parking demand when MOD modes have been shown to reduce vehicle trips or vehicle ownership.

The above potentials are realized mainly due to elimination of fixed cost of car ownership, in exchange for more choices of transportation modes, variable cost, and new types of tradeoffs.

One of the biggest challenges for edge city MOD is competing with personally owned vehicles in a land use context that was designed to provide plentiful, no cost off-street parking. As edge cities urbanize and become denser, opportunities for pricing parking may exist. Since edge cities attract trips from suburban and exurban areas within the region, MOD may not be as affordable as personally owned vehicles unless parking is priced.

Exurban MOD

Exurban development can be defined as low-density residential development within the commute shed of a larger and denser urbanized area. The main distinction between exurbs and suburbs is their lower development density and longer distance from the city center. Although definitions of exurban population density vary, one recent study used the range of 100 to 1,000 people per square mile. The study's authors estimate a residential density of up to four dwelling units per acre. People living in exurbs rely on the automobile for practically every trip purpose, creating notable economic and accessibility constraints for those unable to own or operate a car.

Elements of an exurban scenario include:

- Up to 4 dwelling units per acre (100 to 1,000 people per square mile)
- Within the commute shed of a city center or edge city
- Fewer jobs than dwelling units.

Examples of exurban scenarios include Loudoun County, Virginia (Washington DC, metro); Tracy, California (San Francisco, metro); Peachtree City, Georgia (Atlanta, metro); and Valencia, California (Los Angeles, metro).

Table 14: Examples of Exurban MOD Use Cases

Constraint Type	Constraint	MOD Solutions
Spatial	Long commute distances Limited retail opportunities and community resources	Park-and-ride facilities (to facilitate ridesharing and informal ridematching to job centers) First-and-last mile connections to commuter rail Goods and digital delivery
Temporal	Long travel times	Park-and-ride facilities (to facilitate ridesharing and informal ridematching to job centers) First-and-last mile connections to commuter rail
Economic	Expense of longer trips	Ridesharing app; microtransit and ridesourcing/TNCs (where ridership and/or densities may not be high enough to justify a fixed-route public transit service); innovative payment plans
Physiological	Lack of alternatives to driving	Paratransit and volunteer transport
Social	Negative perception of public transit	Ridesourcing/TNCs, microtransit, carpooling apps

Exurban MOD may allow for increased social and economic inclusion by providing carless and low-income households additional modal options in a built environment that historically has required private vehicle ownership for accessibility.

Rural MOD

The rural context is characterized by very low-development densities. Dwelling units are widely dispersed (typically less than one dwelling unit per acre), so there are fewer opportunities to create efficiency through shared rides. Roadways are rarely, if ever, congested and parking is not a problem, but travel distance for such necessities as healthcare can be insurmountable for non-drivers.

Resources for rural public transit vary considerably by state. While typically the most affordable in terms of housing, the rural context provides the greatest accessibility challenges out of the five built-environment scenario types, with few if any transportation services available to youth, seniors, and the people with disabilities. Automobile ownership is an economic necessity, creating a serious strain on low-income household budgets.

More research is needed to assess potential use cases, viability, and benefits of MOD in rural locations. Rural use cases could include:

1) Access to resource-based jobs (e.g., farms, mining)
2) Access for special needs populations (e.g., older adults, low-income and carless households, and people with disabilities)
3) Access to nearby airports and medical centers
4) Classic forms of MOD not requiring technological access (e.g., traditional carpooling) to overcome digital poverty and poor cellular data access in rural areas
5) Partnership with faith-based organizations and other types of associations and gathering places common in rural communities

6) Receiving goods (e.g., grocery delivery and deliveries from both brick-and-mortar and online retailers)
7) Digital delivery (e.g., leveraging online resources in use cases where digital delivery may be more affordable or more practical)
8) Bringing goods to market (e.g., produce and poultry from rural areas to more urbanized areas for sale).

Table 15: Examples of Rural MOD Use Cases

Constraint Type	Constraint Examples	MOD Solutions
Spatial	Long-travel distances to dispersed job centers, healthcare and limited retail centers in resource-based economies	Ridesharing and microtransit agricultural and prison workers Goods and digital delivery
Temporal	Long travel times	Volunteer transportation network; ridesharing
Economic	Expense of vehicles and fuel Expense of accessing goods and services	Innovative payment plans, volunteer drivers, car trades for transportation service Free and/or low-cost subscription goods and digital delivery options
Physiological	Lack of medical facilities in rural communities	Ridesourcing/TNC and volunteer transport to nearest medical facilities in suburban/exurban areas, CNS delivery of medicine
Social	Lack of mobility services targeted toward rural users	Low-cost MOD with local volunteer drivers, multiple interfaces to access services

Leveraging social capital with mobility represents a key opportunity in rural communities. People in lower-density areas expect to help each other. Because there is essentially no public transportation in many rural communities, sharing rides or accepting a ride from a neighbor are the de facto transportation system for those who do not drive. MOD can improve this grassroots system by expanding the variety of resources used, improving communication among participants (both within an individual community and between communities), and using technology to offer training to community members.

Rural MOD applications may increase social and economic inclusion by providing carless and low-income households additional modal options in a built environment that historically has required private vehicle ownership for accessibility. In some cases, digital accessibility may be more important than transportation accessibility. For example, improving high-speed Internet connectivity could reduce isolation and limit the need for physical trips (e.g., healthcare advice through Skype communication, drone delivery in the future). In cases where a trip is necessary, MOD goods delivery can reduce the need for rural users to make long two-way trips.

Key Takeaways

The key takeaways include:

- A close examination of U.S. urbanization patterns shows that most areas are comprised of five development types: 1) City Center; 2) Suburban; 3) Edge City; 4) Exurban; and 5) Rural.
- In the densest urban areas, MOD has the potential to reduce demand for private automobiles and single occupant travel, reduce demand and more efficiently manage parking, offer short-distance and medium-distance transportation alternatives to private vehicle use, and may help urban centers mitigate congestion and emissions.
- Urban area use cases may include first- and last-mile connections to public transportation; urban goods movement (e.g., CNS); daily commuting and other business trips; school trips; and trips for people with special needs, such as people with disabilities, caregivers, medical trips, etc. Additional use cases may include mobility for special circumstances, including special events and disaster response (e.g., evacuation). MOD may also mitigate public transit congestion during peak periods and offer late-night travel when public transit systems have reduced service.
- Similarly, common suburban and edge city use cases may include first- and last-mile connections to public transportation, daily commuting and other business trips, school trips, trips for low-income and carless households, and trips for people with special needs, such as people with disabilities, caregivers, medical trips, etc.
- One of the biggest challenges for suburban, exurban, and rural MOD is competition with personal vehicles, urban form (both density and design for automobility rather than walkability), and potential costs of MOD per-use versus auto ownership. USDOT can support suburban MOD by improving data collection, analysis, and overall understanding of MOD travel behavior, providing flexible funding sources to encourage public and private partnerships, more flexible parking and zoning codes, and encouraging technological integration and interoperability between the public and private sector through incentives.
- The exurban and rural built environments are characterized by very low-development densities. Common use cases in these ultra-low-density areas may include access to: 1) resource-based jobs (e.g., farms, mining, etc.); 2) special needs populations (e.g., older adults, low-income and carless households, and people with disabilities); and 3) access to nearby airports and medical care.
- Rural MOD requires innovative solutions to address the current gaps. Allowing faith-based mobility subsidies; expanding commuter benefits to MOD (e.g., Internal Revenue Service deductions); and developing volunteer carpool driver programs are potential opportunities for the expansion of rural MOD. Government/USDOT support could be essential in igniting these innovative solutions. For example, initiating a “Smart Rural Communities Challenge” could encourage digital and transportation infrastructure improvements in rural communities.
- A few challenges that may be addressed for all land use environments, including:
  - Multi-jurisdictional issues: For example, how can ridesourcing/TNC trips be subsidized with origins and destinations in different counties (or even crossing state lines)?
  - Price incentives: For example, what is the motivating price point to take an individual five miles out of their way to pool a ride and how much is someone willing to pay?
- American Disability Act (ADA) requirements: While ADA requirements are key for addressing equity issues, they could also prevent MOD from existing in rural communities. However, MOD could cease to exist in rural communities, if microtransit, ridesourcing/TNCs, or any other mode must be ADA accessible when there are fewer ADA users because of lower population densities.

Striking the balance between the two competing factors remains a challenge to be addressed. Additionally, there may be opportunities to leverage employer-based transportation demand management, mobility aggregation, and feebates to support MOD across an array of built environments.

Chapter 5. MOD and Social Equity Considerations

Social equity and environmental justice are important aspects of MOD. MOD can enhance access and opportunities to underserved communities. MOD may also have adverse equity and environmental justice impacts when a particular population or community bears a disproportionate share of the benefits or adverse impacts of MOD (e.g., lack of services in low-income or minority communities). The geographic, economic, and socio-demographic diversity of the United States can create challenges to ensuring transportation equity, requiring special attention by federal, state, local, and private sector stakeholders. While much progress has been made at all levels to remove barriers and improve access to transportation, equity challenges still persist. This chapter provides a more detailed overview of these challenges and how they could affect MOD.

Environmental Justice, Social Equity, and Access Laws and Regulations in Transportation

Environmental Justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, income, or disability with respect to the development, implementation, and enforcement of transportation services, laws, regulations, and policies. *Fair Treatment* means that no group of people should bear a disproportionate share of the negative consequences resulting public agency and commercial operations or policies. *Meaningful Involvement* entails public participation in decisions about activities that impact their transportation service, environment, or health, and publics concerns can influence and will be considered in the decision-making process.

Ensuring meaningful involvement into the transportation decision making process and equal access for protected classes impacted by on-demand mobility services is critical. At the federal level, this can include provisions mandating access for people with disabilities as well as prohibitions against discrimination of protected classes (e.g., race, color, religion, national origin, age, sex, pregnancy, citizenship, familial status, and veteran status). Many of these laws not only prohibit discrimination against the end user but also transportation service workers. At the state level, social equity and environmental justice policies may be incorporated into other laws and regulations, such as insurance regulation, volunteer protections, and livery laws. These state policies may also address the challenges of social inequity by removing barriers or incentivizing private solutions, rather than regulating transportation providers.

A number of laws and regulations have been implemented to ensure access and prohibit discrimination in the transportation sector.

The basis of federal protections is generally codified in the following core laws and regulations:

- ***Title VI of the Civil Rights Act of 1964:*** This law prohibits discrimination based on race, color, and national origin in programs and activities that receive federal financial assistance.

- ***Civil Rights Restoration Act of 1987:*** This law clarifies the earlier definition of "programs and activities" in other civil rights legislation. Under this law, discrimination is prohibited throughout an entire organization or agency, if any part of that agency receives federal financial assistance.
- ***Title 23 Code of Federal Regulations (CFR) Part 200:*** This regulation provides guidelines for implementing the FHWA Title VI compliance program and compliance reviews.
- ***Title 49 CFR Part 21:*** This regulation implements provisions of Title VI for any program or activity receiving federal financial assistance from the USDOT.
- ***Title 49 CFR 37.105:*** This regulation implements equivalent service provisions with the 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.
- ***Executive Order 12898:*** This Presidential Executive Order seeks to avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects, on minority populations and low-income populations, as well as ensure full and fair participation by potentially affected communities in the transportation decision-making process.
- ***Executive Order 13166:*** This Presidential Executive Order ensures individuals whose first language is not English or have limited capability to read, write, or understand English have meaningful access to programs, information, and services by entities receiving federal funding.
- ***The Rehabilitation Act of 1973:*** Section 504 of the Rehabilitation Act makes it illegal for federal agencies, programs, or activities that receive federal financial assistance to discriminate against qualified individuals with disabilities. Section 508 requires federal IT and electronic systems be accessible to people with disabilities.
- ***Americans with Disabilities Act (ADA):*** This law prohibits discrimination against people with disabilities. Title III of ADA requires that private transportation businesses provide accessible-ready vehicles and facilities to persons with disabilities.

Among the core transportation issues that fall to the states are insurance, driver licensing, motor vehicle registration, livery laws, and volunteer protection. Too numerous to list in this report, they impact accessibility, environmental justice and equity. For example, Maine has laws that protect volunteer drivers against unreasonable increases in insurance premiums and allows non-profit organizations to accept cars in trade for senior transportation (Maine Revised Statutes, §2902-F. Volunteer drivers, insurance code, §951, Licensing of dealers).

A number of other laws and regulations may provide protections and rights to employees of on-demand mobility service providers, such as the Title VII of the Civil Rights Act of 1964 and the Age Discrimination Act of 1975.

Key MOD Equity Challenges

The following section highlights five key challenges: 1) discrimination against protected classes; 2) accessibility for older adults and people with disabilities; 3) economic accessibility; 4) digital poverty; and 5) urban and rural divide.

Challenge 1: Discrimination against protected classes. Formal research and anecdotal accounts documenting access and equity concerns for MOD among minorities, women, and people with disabilities are emerging. A recent multi-city study of Lyft and Uber drivers identified a number of racial equity concerns. (Please see sidebar for more information on this study.)

Equity Challenges Examples in Shared Mobility

A recent multi-institutional research study of 1,500 rides taken in Seattle and Boston found that Uber drivers in Boston were over twice as likely to cancel rides of passengers with names perceived to be of African American origin versus Caucasian names (O'Brien S. , 2016). Also, drivers took women on longer, more expensive rides. Of the 581 ridesourcing/TNCs trips logged, African-American travelers waited on average 20 percent longer than Caucasian travelers to have their ride accepted on Lyft or UberX, and it took about 30 percent longer for African-American travelers to be picked up than Caucasian travelers using UberX (Kubota, 2016) (Ge, Knittel, MacKenzie, & Zoepf, 2016). Traditional taxi drivers in Seattle reportedly stopped more often for Caucasian riders than for African Americans (Scott, 2016). Similar discrimination reports have been cited with other sharing economy service providers (e.g., AirBnB) (O'Brien S. , 2016).

Recipients of USDOT funding typically include state departments of transportation (DOTs); state motor vehicle administrations; metropolitan planning organizations; and regional, state, and local public transit operators. Potentially unclear legislation and regulatory guidance coupled with the lack of legal precedents for MOD creates uncertainty regarding whether private sector services not receiving federal funding are subject to laws and regulations protecting users from discrimination. This is especially the case for Shared Mobility operators that rely on independently contracted drivers through an open platform, whose actions may not be interpreted as the direct responsibility of the operator. In spite of uncertain compliance requirements, some scenarios may create clear compliance requirements. For example, both Uber and Lyft have partnered with numerous public transit agencies. A number of these partnerships involve subsidized Lyft rides, joint marketing, and other types of in-kind support. In cases where public transit agencies receive federal funding to pay for a portion of private sector fares, Lyft and Uber (as well as other services) become an extension of the public transportation system. As such, the formation of these partnerships with agencies receiving federal dollars suggests a statutory and regulatory compliance requirement with many of the laws and regulations previously outlined.

Challenge 2: Accessibility for Older Adults and People with Disabilities. Another challenge related to MOD is service for older adults and people with disabilities. Mandated under federal law, demand-responsive service provides assistance to passengers with limited mobility vis-à-vis dial-a-ride or paratransit services. These services often have limited geographic coverage, require advance scheduling notice, and are generally very expensive to operate on a per trip basis (compared to public transportation and other modes). Demand responsive MOD services for people with limited mobility may be one way of complying with federal requirements and potentially offer users enhanced services (e.g., reduced wait times) and at reduced cost (e.g., to the end user, public agency, or both). However, MOD can also raise a number of equity concerns, particularly around the lack of demand-responsive service for passengers with limited mobility when MOD modes do not offer accessible services or equivalent accessible alternatives.

A number of services have confronted numerous complaints and lawsuits alleging violations of ADA (Kubota, 2016) (Ge, Knittel, MacKenzie, & Zoepf, 2016). Uber, for example, has responded by implementing UberWAV service allowing passengers with disabilities to request wheelchair accessible vehicles. Similarly, UberASSIST offers regular vehicles with specialized driver training and is available in 13 U.S. cities. However, these services are not available in all markets, and even in markets where they are available, passenger complaints regarding the lack of UberWAV vehicles and UberASSIST drivers are frequently reported. However, a CNN special investigation checking the availability of UberWAV found consistently zero UberWAV vehicles in San Francisco, Uber's flagship market, and zero to one vehicle availability with 25- to 45-minute wait times in Los Angeles and Portland (Kelly, 2016). Drivers have also expressed concerns about perceived increased liability and risks associated with picking up passengers with disabilities, suggesting that this challenge remains among MOD services.

Challenge 3: Economic Accessibility. In addition to serving passengers with disabilities, a number of economic challenges can be associated with MOD. Typically, these challenges can be classified into three areas: 1) serving unbanked and underbanked users; 2) the affordability of MOD services; and 3) barriers to using volunteer drivers.

Challenge 3a: Serving Unbanked and Underbanked Users*.* Many MOD providers require users to have access to a credit or debit card for registration and/or payment, hindering use by low-income, minority, younger, and less educated users. These groups tend to rely more on cash, and have lower access to banking services (Serebrin, 2016). A 2015 Federal Deposit Insurance Corporation (FDIC) survey found that Seven percent of U.S. households were unbanked, meaning that no one in the household had a checking or savings account (Federal Deposit Insurance Corporation, 2015). "An additional 19.9 percent of U.S. households were underbanked, meaning that the household had an account at an insured institution but also obtained financial services and products outside of the banking system" (Federal Deposit Insurance Corporation, 2015).

Challenge 3b: Affordability*.* According to a *New York Times* critique of shared mobility services, a number of these options are more convenient, but they not necessarily cheaper (Manjoo, 2016). In Helsinki, Finland, the Kutsuplus program was widely critiqued as having too few vehicles and too large of a service area, creating high user fees. The program had a service area of 100 square kilometers (approximately 38 square miles) with a fleet of 10 shuttles (later expanded to 15). This resulted in higher program costs and fares. A base fare of $4.75 plus $0.60 per kilometer was charged (about $0.97 per mile) (Shared-Use Mobility Center, 2016) (Barry, 2013). Additionally, questions of consumer affordability often arise around the use of surge pricing by ridesourcing/TNC providers. Surge pricing occurs when a shared mobility operator raises the price of its service in response to an increase in demand. Proponents of surge pricing argue that dynamic pricing can help increase supply and temper demand. However, critics frequently note that uncertain consumer costs can make a ridesourcing/TNC providers less desirable or reliable, particularly among low- to moderate-income user groups.

Challenge 3c: Barriers to Using Volunteer Drivers. This is of paramount importance to non-profit volunteer transportation providers serving seniors and other special needs populations. The largest MOD expense is labor, so when citizen volunteers are willing to use their own vehicles and donate their time to drive others, issues such as increases in insurance premiums or fear of policy cancellation are serious barriers to service. This is an important concern, because usually the recipients of these volunteer services are older people who can no longer drive themselves safely. To address this issue, Maine passed a law in 1995 that prohibited insurance companies from unfairly or unreasonably increasing premiums simply because a policy holder uses a vehicle to provide rides as a volunteer. The Maine law has been replicated in Florida, Illinois, Maryland, Vermont, and Connecticut, but many states have still not revised their statutes. Other barriers to the use of private resources include prohibitions on charging fares for rides delivered by volunteers (Minnesota) and prohibitions to reimbursing volunteers for expenses, if a fare is charged (Georgia).

The role of the non-profit sector in transportation for seniors is growing as the population ages. Between 2012 and 2050, the over 65 population will almost double, increasing from 43.1 million to 83.7 million

(Ortman, Velkoff, & Hogan, 2014). While age *per se* is not a disability, the frailty that comes with it frequently makes both driving and traditional mass transportation inaccessible. For a large portion of the nation's senior population, non-profit MOD may be a more viable option, but it is often provided by volunteers through local services that lack the marketing and technological capabilities of for-profit operators. Despite this limitation, non-profit MOD operators are increasingly using software platforms to manage service logistics and finances and sharing resources via larger umbrella organizations, such as Independent Transportation Network (ITN) America.

Efforts by the World Health Organization's Global Network of Age Friendly Communities and Cities, launched in 2010, and by the American Association of Retired Persons' Network of Age Friendly Communities, started in 2012, have fueled the movement toward senior-oriented planning. Transportation is one of the eight domains communities must address to become an age-friendly community. Smaller communities (and there are approximately 10,000 incorporated entities with a population of less than 1,000 in the U.S.) are turning to volunteer transportation networks. In rural America, MOD must include private, volunteer resources, because the distances are too long and the costs are too great for either private for-profit solutions or public subsidy to meet most of the demand.

Challenge 4: Digital Poverty. While some MOD modes can be accessed without a smartphone, being able to aggregate, repackage, and provide these services for on-demand trip planning, booking, and payment generally require an Internet-connected mobile device. Lack of mobile Internet access can inhibit users from participating in many MOD services. One major equity concern of MOD is the lower rate of use of smartphones among people who are older, have lower incomes, or have disabilities, often referred to as the digital divide (Pew Research Center, 2017) (Anderson & Perrin, 2016). Since the majority of shared mobility services are accessed by a smartphone, lack of familiarity with and access to mobile and web technology can preclude these populations from accessing MOD services that could save them time or money.

Challenge 5: Service Accessibility in Rural Communities. The availability of service options in rural communities is another equity challenge. Traditional mass transportation solutions, such as buses, trains, and airplanes are generally more cost effective in urban areas due to increased demand and a potential pool of riders. This in turn often yields a higher quality of service, such as more robust networks and shorter headways between departures. The same kinds of logistical and financial constraints that impact mass transportation systems typically effect shared mobility services, as well. MOD may be able to enhance accessibility and mobility in rural communities; however, more research and field operations tests are needed to test MOD operations and service models in the rural context.

Table 16 identifies proposed solutions to address each of these five challenges.

Table 16: Proposed Solutions to Address Equity Concerns Pertaining to MOD

Strategy	Example (if available)	Challenges Addressed
Legislative and/or regulatory guidance on the applicability of existing federal and state laws and regulations on private sector mobility services	Maine law that protects volunteer drivers from unreasonable insurance increases	#1 #3c
ADA consumer protections in local ordinances	In October 2014, the Austin City Council adopted an ordinance regulating ridesourcing/TNC, which among other things mandated that ridesourcing/TNC drivers cannot refuse service or charge higher fees to passengers with disabilities.	#2
Wheelchair accessible vehicles/equipment	In Berkeley, CA, non-profit City CarShare introduced the nation's first wheelchair accessible carsharing vehicles in 2008, known as AccessMobile. City CarShare expanded the program to include wheelchair-accessible vans in San Francisco. In 2015, Buffalo CarShare (now Zipcar) became the second carsharing operator with a wheelchair-accessible van, after acquiring a van from City CarShare (Susan Shaheen, unpublished data, 2015). Uber offers two programs – UberWAV and UberASSIST. UberWAV offers passengers with disabilities a dispatch service to wheelchair accessible vehicles (UberWAV, n.d.). UberASSIST drivers receive special training by third-party organizations to help riders access and egress vehicles, as well as appropriate handling for wheelchairs, walkers, and scooters (UberASSIST, n.d.). BCycle, a national bikesharing equipment vendor, offers a non-standard bicycle for city fleets, including a tricycle that has been deployed in several cities since it was introduced in 2013. The tricycle can make bikesharing more accessible to people with disabilities who are unable to ride a conventional two-wheeled bicycle (Maus, 2016). Since 2015, bikesharing operator Zagster has been launching three-wheel adaptive bicycles in numerous cities across the United States (Zagster, 2016). In Summer 2017, the Portland Bureau of Transportation will be launching an adaptive bicycling pilot project with BIKETOWN Bike Share (Portland Bureau of Transportation, n.d.).	#2

Strategy	Example (if available)	Challenges Addressed
Wheelchair accessible service fund	In Seattle, WA, taxis and ridesourcing/TNC operators pay a $0.10 per ride surcharge for all rides originating in the city “to offset the higher operational costs of wheelchair accessible taxi (“WAT”) services for owners and operators including, but not limited to: vehicle costs associated with purchasing and retrofitting an accessible vehicle, extra fuel and maintenance costs, and the time involved in providing wheelchair accessible trips” (City of Seattle, 2014).	#2
API integration with paratransit	Paratransit services may operate more cost effectively by developing smart dispatch systems that identify certain trips better served with MOD. A number of public transit agencies are pursuing request for proposal initiatives that are soliciting bids for private MOD providers to participate in paratransit pilots and to build software extensions that allow for shared mode dispatching. In Massachusetts, MTBA will subsidize Uber and Lyft as part of a pilot program to provide lower cost on-demand service for paratransit customers (Office of the Massachusetts Governor). Lyft is also working on an initiative with a vendor that would enable automatic “smart dispatch” and assign rides that are best served by paratransit and ridesourcing (Emily Castor, unpublished data, July 2016). This initiative would allow telephone dispatch operations, thereby negating the requirement for smartphones or user (Lyft) accounts. Lyft has a similar partnership with the National Medtrans Network in New York City to offer non-emergency medical transportation for senior citizens 65 and older (Tech-enhanced Life).	#2 and #3b
Cash payment at point-of-sale	Bikesharing users in Chicago and Arlington County (Virginia) allow participants to pay for bikesharing memberships using cash (Greenfield, 2015) (Capital Bikeshare, 2015).	#3a and #4
Cash or money order payment at service provider location	Buffalo CarShare (now defunct) allowed members to pay using money orders (Creighton Randall, unpublished data, March 2014).	#3a and #4
Cash payment at third-party locations or services	In Philadelphia, Indego bikesharing partners with PayNearMe, an electronic transaction network that allows bikesharing users to make online purchases using cash at nearby retail chains (Market Wired, 2015).	#3a and #4

Strategy	Example (if available)	Challenges Addressed
Use of prepaid cards	The MasterCard Aid network has launched a pilot program with Mercy Corps and the Serbian Ministry to labor to distribute prepaid debit cards to eligible refuges traveling through Serbia. During the pilot, approximately $75,000 was distributed to approximately 400 families and individuals. More than $59,000 was spent on transportation, food, medications, and lodging (Grimes, 2016). Uber now sells gift cards a retail locations as a solution for unbanked customers which are available online, but also at retail locations[5]. Transit agencies sometimes have CPOS agreements with merchants to allow customers to add value or pass products to their cards (or purchase pre-loaded fare cards)[6].	#3a and #3b
Direct carrier billing (to mobile services or another utility provider)	An Indego BikeShare (Philadelphia) founding member proposed linking payments (vis-à-vis a key fob/membership card to mobile phones), allowing low-income users to pay membership and usage fees with their phone bill, eliminating the need for smartphone and data access (Schmitt, 2012). By billing usage to a person's phone bill, the bill can be paid at a utility retail storefront, potentially negating the need for both data access and a credit/debit card.	#3a
Payment with debit card (in place of credit cards)	Many bikesharing operators accept debit card payment (in place of a credit card). However, depending on system design, a debit card payment may require placing a security hold on the account requiring account funds. For example, Bay Area Bike Share places a security hold of $101 on credit and debit cards, which remains on the account for 5 to 10 days (Bay Area Bike Share, n.d.).	#3a
Personal Transportation Accounts	This financial instrument, managed through the ITN*Rides* platform, holds transportation assets in various forms, so volunteer credits, equity from vehicles traded to pay for rides and third-party payers, such as merchants and healthcare providers, can help to pay for rides.	#3c
Linking to family accounts	This allows relatives and minors to link to another family member's account (e.g., a child does not have a credit card, but a parent has a user account with a credit card on file).	#3a and #3b

[5] https://www.uber.com/gift-cards/

[6] https://farepay.rideuta.com/faq.html

Strategy	Example (if available)	Challenges Addressed
Free rides, subsidies, vouchers, and discount codes	In September 2016, the Massachusetts Bay Transportation Authority (MTBA) announced that it will begin subsidizing ridesourcing/TNC use for special needs populations that would otherwise access MTBA's paratransit service. MTBA's paratransit service and the ridesourcing/TNC partnerships will operate concurrently during the pilot program (Office of the Massachusetts Governor, 2016). The City of Altamonte Springs, Florida is subsidizing 20% of a ridesourcing/TNC fare that starts or ends in the city. The fare subsidy increases to 25%, if a trip begins or ends at a local light rail station (Sisson, 2016). Capital Bikeshare (Washington DC) offers $5 memberships in partnership with six participating organizations. Users who signup also receive free helmets and cycling classes (Sturdivant, 2016). Montgomery County Maryland offers free bikesharing memberships to Capital Bikeshare users based on income eligibility under a program known as MCLiberty. Similar to Washington DC, MCLiberty participants also receive a free helmet and bicycle safety training (Montgomery County Government, n.d.).	#3a and #3b
Partnerships with housing authorities and non-profit organizations	San Francisco's City CarShare, now available through Getaround, had a program that includes subsidies for membership and usage fees for low- to moderate-income users. To apply for the subsidy, prospective users were referred by one of six project partners that serve low- and moderate-income residents and clients (City CarShare, 2015). City CarShare was also one of the few MOD providers offering services geared directly toward older adults through its partnership with NextVillage, a San Francisco-based non-profit working to enhance the mobility of older adults. NextVillage paid for a complimentary one-year carsharing membership for volunteers who donated 12 hours on a quarterly basis to drive senior citizens to appointments and errands (City CarShare, 2014). The fate of these programs is currently unknown as the access to vehicles via Getaround relies on a P2P model with no corporate accounts or membership fees.	#2 and #3a
Partnerships with financial institutions (Serebrin, 2016)	Capital Bikeshare's Bank on DC is a partnership between Capital Bikeshare and two financial institutions to provide low-cost "starter" bank accounts to prospective bikesharing users and raise consumer awareness about the benefits of bank products. New York City's CitiBike, Ithaca CarShare, and Chicago's IGo (now defunct) have implemented similar partnerships to reach unbanked and underbanked users in their regions (Kodransky & Lewenstein, 2014).	#3a

Strategy	Example (if available)	Challenges Addressed
Partnerships with the healthcare industry	ITN*America* has partnered with Regeneron Pharmaceuticals to provide free eye health care rides in more than 40 communities.	#3c
Partnerships with third-party web-based platforms	Lyft is developing a third-party web-based platform for dispatching that allows special needs populations to dispatch a ride without having a Lyft account or smartphone access (Emily Castor, unpublished data, July 2016).	#2, #3a and #4
Telephone dispatch	Services, such as GoGo Grandparent and Uber Central, offer telephone dispatch services for ridesourcing and courier network services. ITN*America* offers telephone ride-coordination from all affiliates in the network.	#2 and #4
Digital kiosks	The City of Altamonte Springs, Florida is trying to address the digital divide challenge by offering a smartphone app and a digital kiosk for the city's new flexible route, on-demand bus system (Sisson, 2016). In May 2016, CIVIQ Smartscapes, a smart city communications manufacturer announced the launch of WayPoint at the American Public Transportation Association (APTA) conference. WayPoint is a digital kiosk that provides the public with real-time transportation information, wayfinding, and service announcements. The system can employ optional features, such as WiFi, charging ports, and emergency 911 intercoms (CIVIQ Smartscapes, 2016). Because of the public computer kiosks, these Internet-enabled kiosks could conceivably be used to offer access to MOD without the need of owning a smartphone. The system is currently being deployed in New York City. Another vendor, Sidewalk Labs will install over 100 kiosks (across 25 blocks) in the City of Columbus, as part of the US Department of Transportation's Smart City Challenge grant. The kiosks will provide free WiFi access points for disadvantaged users who cannot afford access to mobility information through a personal device (Foxx, 2016). A partnership between Sidewalk Labs and Transportation for America (T4A) will study how technology can help cities address transportation challenges. T4A will study the state of current transportation policy and technology in US cities to guide the design of future connected cities (Transportation for America, 2016).	#4

Key Takeaways

The key takeaways include:

- While environmental justice and social equity have been an important consideration for the transportation sector, there is limited statutory and regulatory guidance, and legal precedents on how these laws may impact private sector transportation modes, such as ridesourcing/TNCs.
- Equity can be difficult to analyze because there are several types of equity issues impacting the transportation network. With the proliferation of private mobility services often requiring a smartphone, mobile internet access, and/or credit and debit card access, these services can raise a wide array of potential environmental justice and social equity issues, including digital poverty, unbanked and-underbanked users, service access to low-density and rural areas, affordability, and access for older adults and people with disabilities.
- MOD should enhance mobility, access, and economic opportunity for all travelers. MOD can raise equity concerns when users are required to have smartphones (or data networks) to access services, when fares are unpredictable or expensive, or when service is unavailable or inaccessible (e.g., low-density communities, older adults, or people with disabilities).
- MOD can also create opportunities to enhances access and equity by providing increased mobility options (e.g., fares, routes), increased travel speed and reliability, critical first-and-last-mile connectivity, and expanded coverage to historically underserved users or communities. Legislation and regulation can play a notable role in safeguarding transportation equity by mitigating emerging MOD technological and access barriers, though more research and policy guidance is needed to clarify the applicability and scope of existing statutes.

Chapter 6. Relevant Policies and Standards to Enable MOD

MOD has the potential to offer regions a variety of transportation and environmental benefits, such as increased mobility; greater environmental awareness; reduced vehicle emissions; and first-and-last-mile connections to public transportation. For more on the impacts of shared modes, please refer to Federal Highway Administration Report FHWA-HO-16-022 *Shared Mobility Current Practices and Guiding Principles*.[7] While innovations in MOD have the potential to provide societal benefits, public policy is required to leverage the positive impacts of MOD and tame the potential negative impacts.

MOD-specific public policies have the potential to enhance accessibility and quality of life in a variety of urban and other land use contexts. Understanding relevant MOD policies and regulations and identifying policy gaps can inform the multimodal transportation operations management DSS and the strategic policy and regulatory responses.

Eight Areas of Public Policies and Regulations that Impact MOD

Local, regional, and state agencies can have a substantial impact on the success and operations of MOD through public policy, legislation, and regulation. Local and regional governments can also represent important MOD partners due to their role in transportation planning, public transit, and parking policy. Eight common areas that impact local and regional governments and MOD include:

1) ***Health, Safety, and Consumer Protection:*** Local and state governments and public agencies have established administrative regulations, ordinances, and laws that may require insurance, driver physicals, and/or the disclosure of factual information to provide transparency about services and/or prevent the dissemination of inaccurate or misleading information (Shaheen et al. 2016). Enforcement of accessibility and equity-related policies, such as Title VI and ADA, represent another important consumer protection role executed by public agencies.
2) ***Taxation:*** The role of taxation and tax incentives for MOD services, such as the potential applicability of rental car excise taxes, sales taxes, and commuter tax breaks, are important public policy issues impacting user costs and the potential financial viability of MOD services in some markets.
3) ***Insurance:*** Insurance coverage limits and requirements can directly impact the cost of MOD services and their ability to legally operate. There may also be inconsistent insurance

[7] https://ops.fhwa.dot.gov/publications/fhwahop16022/fhwahop16022.pdf

requirements for taxis and ridesouring/TNCs, which may negatively impact some MOD service providers.

4) ***Parking and Access to Rights-of-Way:*** Local and regional agencies typically manage on-street curb space for transportation services.
5) ***Equity and Accessibility Issues:*** Public agencies have ethical and legal requirements to ensure that transportation services are accessible by everyone. Public agencies can play a critical role in monitoring equity, refining definitions, monitoring trends, and developing policies that address potential emerging issues (e.g., digital and income divide).
6) ***Full and Fair Participation:*** Public agencies have similar ethical and legal requirements to ensure full and fair public participation in the transportation decision-making process. This may include ensuring the ability of the public to participate and provide comments on existing and proposed public policies, the siting of MOD services in the public rights-of-way, and public-private partnerships and contracts with MOD operators.
7) ***Data Sharing, Privacy, and Standardization:*** Public agencies have a role in developing best practices that identify data standards and balance data sharing (open data) and privacy among individuals, companies, and public agencies, particularly among app-based MOD service providers.
8) ***Livery Laws:*** Many municipalities and state governments regulate for-hire vehicle services, such as taxis, ridesourcing/TNCs, liveries, and limousines.

Table 17 summarizes examples of eight areas where public policy can impact MOD.

Table 17: Policies Relevant to MOD

Policies	Relation to MOD	Examples
Health, Safety, Consumer Protection	Public agencies, local and state governments establish guidelines, regulations, and ordinances that impact MOD vendor operations and use of customer data	• Helmet laws for bikesharing users • Driver background check and training requirements for ridesourcing/TNC vendors • Pricing regulations for ridesourcing • Draft TNC app user privacy legislation in California
Taxation	Unclear definitions and service models for MOD have led to confusion among state and local government regarding taxation	• Rental car excise taxes apply to carsharing vendors • Commuter tax breaks apply to some microtransit vendors (e.g., Via)

Policies	Relation to MOD	Examples
Insurance	State governments set insurance policies impacting carsharing, bikesharing, ridesharing, and for-hire vehicle services	• Oregon requires P2P carsharing platforms to insure vehicle while in use; classifies the use as non-commercial • Ridesouring/TNC vendors have three distinct insurance coverage periods: 1) driver has app open, 2) driver en-route for pick-up, 3) rider is in vehicle • California protects employers from worker's compensation claims involving vanpool collisions, if part of government mandated program • Uncertain future insurance regulation for AVs • Maine has a law that protects volunteer drivers from unfair or unreasonable increases in their automobile insurance because they use their vehicles to drive others
Parking and Rights-of-Way Access	State and local governments set policies that impact access to public roads (e.g., HOV lanes on highways) and parking spaces	• California AB 2154 allows local government to provide on-street parking for carsharing and ridesharing (i.e., carpools and vanpools) vehicles • Most bikesharing stations are granted access to public land through real estate license, easement, memorandum of understanding • San Francisco charges a per-stop fee to commuter shuttles accessing designated loading spaces
Equity and Accessibility	Title VI, Executive Order 12898, ADA, and other statutes and regulations require projects and agencies receiving direct/indirect federal funding (including publicly supported MOD projects) not to exclude or disproportionately impact protected classes.	• Austin prohibits ridesourcing/TNC drivers from refusing to serve or charge higher prices to riders with disabilities. • DC Capital Bikeshare connects unbanked users with financial institutions that can provide banking and debit card access.
Full and Fair Participation	Public agencies are legally required to engage the public for all federally funded programs under Title VI, Executive Order 12898, the National Environmental Policy Act (NEPA) (and state-level equivalent environmental reviews), along with other statutory provisions and regulatory guidance.	• NYC's CityBike deployment accompanied by a concerted multi-lingual and multi-media public engagement effort to determine station siting and allow for public feedback

Policies	Relation to MOD	Examples
Data Sharing, Privacy, and Standardization	Establishing data standards and facilitating data sharing while protecting consumer privacy allows MOD services to aggregate modes, facilitate multimodal planning, booking, and fare payment. Data sharing can also be used to enhance the quality of real-time data services for all users.	• During the 2014 World Cup in Rio de Janeiro, the government obtained driver navigation data from Google's Waze app and combined it with information from pedestrians who use the public transportation app Moovit, providing local authorities with valuable real-time information about the transportation network. Together, these services could jointly aggregate and identify thousands of operational issues ranging from congestion to roadway hazards (Olson, 2014).
Livery Laws	Local (and some state) agencies typically regulate for-hire vehicle services such as taxis and ridesourcing/TNCs. Regulations can include a variety of provisions such as background checks for drivers, drug testing, vehicle safety inspections, and insurance requirements.	• Austin ratified a municipal ordinance regulating ridesourcing/TNCs that includes a number of provisions, including the establishment of minimum insurance requirements, driver training requirements, a limit on the number of consecutive hours a driver can work, and prohibitions on refusing to pick up passengers or charging more for disabled passengers. In December 2015, the city council amended its local ordinance to require fingerprinting of ridesourcing/TNC drivers.

(Shaheen, Cohen, & Zohdy, 2016)

A number of public agencies are involved in regulating MOD, often with shared or overlapping responsibilities. Identifying the most appropriate and “primary” agency may be difficult for policymakers. Elected officials and regulatory bodies should develop public policies aimed at increasing accessibility, enhancing mobility, and maximizing the transportation and environmental benefits of MOD, such as decreasing energy consumption, reducing congestion and private vehicle reliance, and improving air quality (Cohen & Shaheen, 2016). Documentation of social and environmental impacts should be collected whenever possible to support policy development and policy revisions, as appropriate (Cohen & Shaheen, 2016). The development of consistent public and private sector definitions; creation of metrics, models, and methodologies to measure impacts; development of standards to facilitate multimodal integration; and creation of standards that facilitate open data, while protecting consumer privacy are four key areas that can guide further development of MOD.

Standards

Similar to policies and regulations, standards help level the playing field, enabling interoperability, and encouraging compatibility in MOD. Standards also simplify product development and speed time-to-market. Standards development for MOD are critical in the following key areas:

- ***Consistent Public and Private Sector Definitions:*** Consistent legal definitions of service models are essential for mainstreaming MOD. Legal definitions form the foundation for subsequent policy development related to taxation, insurance, rights-of-way, parking, zoning, and other public policy issues. The lack of formal definitions can create substantial barriers to developing public-private partnerships and finding partners. Public agencies and industry associations should work together to develop uniform, clear, and concise definitions of MOD services. Additionally, definitions should be developed around service characteristics and not technologies.

- ***Development of Metrics, Models, and Methodologies to Measure the Impacts of MOD:*** The development of data metrics, models, and methodologies is necessary to measure the travel, economic, social, and environmental impacts of MOD for public agencies and policymakers. Additionally, developing these tools will enable public agencies to forecast the impacts of MOD and guide future public policy and planning decisions related to urban planning, public rights-of-way, parking management, and zoning.
- ***Standards to Facilitate Multimodal Integration:*** Seamless connectivity among multiple transportation modes is recognized as a best practice to enhance accessibility, support sustainability, and bridge first-and-last-mile gaps in the transportation network. Achieving multimodal integration requires standards for two key components: 1) design guidelines to facilitate infrastructure integration and 2) technological standards to facilitate information and fare integration.
- ***Privacy and Open Data Standards:*** Public and private partnerships to standardize data, share data, and protect sensitive data can be key to leverage the benefits of MOD on the transportation network and encourage innovation (Shaheen & Cohen, 2017). MOD operators typically track several important data points—the origin and destination (e.g., the pickup and return location for a carsharing or bikesharing vehicle or ridesourcing passenger), travel time, and trip duration (Shaheen, Cohen, & Zohdy, 2016). Sharing data across public and private agancies is key to to the success of MOD. Providing open data will allow local governments and private enterprises to offer real-time transportation information to their communities and allow for more advanced forms of technological multimodal integration through third-party APIs and other data sharing techniques. As data become more open, protecting consumer privacy and proprietary information will become paramount. MOD can only succeed if consumer data can be safely shared between services (e.g., joint fare payment among multiple modes). As such, privacy and open data standards are critical to ensuring compatibility for a variety of uses and platforms.
- **Standardization for the Underlying Technologies Used in Different MOD Apps**: To aggregate MOD services and integrate a variety of real-time information sources, smartphone apps (and other web-based services) must be able to interface, provide necessary data, and disseminate information. As the IoT and Machine-to-Machine (M2M) communication are expanding, MOD-related apps should be able to interact with other transportation-related interfaces for a user-friendly and integrated experience.
- **Standardization of Mapping and Navigation Technologies**: As connected and automated vehicles are emerging, the standardization of mapping and navigation technologies is critical. Connected and automated vehicles “include more low-cost, high-resolution sensors, will capture and upload these data to a central, cloud-based repository so that automotive companies, such as HERE, can crowdsource the information to build highly accurate, real-time precision maps. These dynamic 3D maps will provide a complementary data set to vehicles' ADAS sensors for an overall smoother driving experience. However, a big challenge for the new mapping paradigm is the lack of standards, coupled with high levels of fragmentation in the automotive industry.” (Engineering360, 2016).

Key Takeaways

The key takeaways include:

- As MOD continues to grow and expand, the critical need to develop and manage public policy will also expand. Advanced technologies coupled with innovative and unclearly defined service models will increase the need for legislative and regulatory guidance (Cohen & Shaheen, 2016). Public agencies can have a significant impact on MOD. Common areas that can involve MOD public policy include:
  - Health, safety, and consumer protection
  - Taxation
  - Insurance
  - Parking and access to public rights-of-way
  - Equity and accessibility
  - Full and fair participation
  - Data sharing, privacy, and standardization
  - Livery laws.
- Policies and regulations can support innovation in MOD to enhance mobility, safety, and sustainability. In light of new services and innovations, state and local governments may need to re-evaluate current regulations for market entry, geographic coverage, extent of service, and service quality for traditional and new forms of MOD (Transportation Research Board, 2015). This assessment should also include public safety requirements.
- Policies and regulations should also address an array of equity issues, such as ensuring access for people with disabilities, unbanked and underbanked users, and people without access to smartphones or the mobile Internet.
- Standardizing technologies, security/privacy, and open data standards could accelerate the pace of MOD growth and support multimodal integration.

Chapter 7. MOD Enabling Technologies

Technological advancements are a key enabler of MOD services. Advances in ICT; location-based and satellite navigation services; data storage, analytics, and dissemination capabilities; and the growth of cloud computing are all contributing to the growth of MOD. This chapter discusses how each of these underlying technologies are enabling MOD. Understanding the role of these technologies could help the USDOT better identify how to advance MOD and support multimodal transportation operations management.

Wireless Networks and Mobile Technologies

The success of MOD (both passenger and goods movement) depends on a reliable and secure communications infrastructure. Recent advances in communications technologies are transforming the transportation ecosystem by gathering information from the passengers/goods services and feeding it back to the system (usually in the form of an app or API) to better serve users, ensure safe navigation, and manage traffic.

The advances in wireless and mobile technologies connect travelers and goods to the service providers more quickly and easily. As connected and automated vehicles come to market, the role of wireless technologies becomes even more essential. The integration of vehicles, smartphones, and cloud connectivity is facilitating and mainstreaming the flow of information among drivers and infrastructure to enhance mobility, delivery, and systems performance for all stakeholders.

The underlying wireless communication technologies include DSRC, cellular Long-Term Evolution, Wi-Fi, satellite, P2P technologies, visible light communication, device-to-device communication, and M2M communication, among others. Perhaps the most disruptive among these technologies may be 5th Generation (5G) wireless systems that offer a unique capability to transmit gigabits of data with a very low latency. The evolution of 5G enables better utilization of M2M communication and IoT. M2M and IoT allow for improvements in connectivity among travelers and goods delivery in the transportation network—a key piece of a smart city.

While there are a range of latency and reliability issues that must be addressed for a robust wireless communication network, communication security remains a critical challenge. A highly secure communication platform is necessary to ensure the safety and reliability of a connected transportation network. Improvements in technologies, such as encryption, VPN, and secure tunnels, are needed to prevent intrusion and malicious security breaches. Moreover, these security systems must be easy to deploy and manage and include centralized identity management equipped with authentication and authorization techniques (Yousuf & Kandarpa, 2014).

Location-based Technologies

As more mobility and goods movement services come online, more accurate positioning and mapping technologies are essential for the entire transportation sector. To meet these needs, researchers and product manufacturers are continuing to develop location-based technologies that are smaller, faster, and more capable than their predecessors at lower price points. This enables OEMs to include automation-enabling technology in a wider range of vehicle sizes and price points. In parallel, system redundancies are providing precise timing in situations where Global Navigation Satellite System (GNSS) is unavailable (Yousuf & Kandarpa, 2014).

Conversely, mapping technologies focus mainly on coarse-level maps that would allow a vehicle to navigate long corridors, cities, etc., as well as mapping the immediate area around a vehicle to determine its relative position and orientation with respect to its surroundings. These algorithms must operate in real time and be able to handle challenging conditions and dynamic environments. Researchers are continuing to advance simultaneous localization and mapping (SLAM) techniques to improve the capabilities of visual SLAM in challenging lighting conditions (e.g., dawn, dusk, night, rain, fog), as well as changing environments (e.g., seasonal changes, cities). Researchers have also been developing techniques for cooperative vehicle mapping that allow one vehicle to use the perception capabilities of another vehicle to more safely navigate through its environment (Yousuf & Kandarpa, 2014). Several challenges in this area need to be addressed including indoor spaces where GPS fails due to satellite signal degradation and multi-path propagation of radio signals.

In addition to companies such as Google that have traditionally been collecting and disseminating mapping data, some of the shared mobility actors such as Uber are also entering this realm. Uber announced in 2016 that it will spend $500 million on mapping to better direct its drivers (Morris, 2016).

Automated Vehicles

Most automobile manufacturers are working on the development of automated vehicles. Automated vehicles coupled with smart infrastructure offer tremendous opportunities to enhance safety, mobility, accessibility, and the environment. Some automated vehicle applications could include automated taxis, self-driving shuttles, and automated services providing first/last-mile travel to destinations and mobility hubs.

Automation adds more options for vehicle ownership models. In addition to the current two options of: 1) personally owning and driving vehicle and 2) shared and driven vehicle, there will also be the options of 3) personal automated vehicles and 4) shared automated vehicles. Over the next decade, it is anticipated that automated vehicles will be commercialized, enabling many innovative options for passengers and goods movement. The adoption and mainstreaming of automated vehicles will likely require physical and digital infrastructure design enhancements. For more information on the opportunities and challenges of automated (and connected) vehicles, please see USDOT Report FHWA-HOP-17-001 (USDOT, 2016).

Wide usage of automated vehicles could also affect our current infrastructure. For example, the need for signalized intersections and parking may not be as critical as it is now, but in the world of automated vehicles, a smart infrastructure will be essential. This will open new ways of thinking about how to use the current infrastructure to better serve the needs of the future transportation network.

Connected Vehicles

"Connected vehicles (CV) enable safe, interoperable networked wireless communications among vehicles, the infrastructure, and passengers' personal communications devices" (Intelligent Transportation Systems Joint Program Office, n.d.). While automated vehicles rely mainly on sensors, radar, and light detection and ranging (LIDAR) to navigate around the roads, connected vehicle technologies provide greater connectivity among vehicles, infrastructure, and individuals to enable safety, mobility, and environmental benefits. Connected vehicle technologies allow vehicles to send and receive information about their movements in the network—offering unprecedented opportunities to provide more responsive and efficient mobility solutions in real time and in the long term. It has been argued that a true level-5[8] autonomous vehicle will not be possible without connected vehicle technology.

Connected and automated vehicles rely on data from their surroundings and produce a lot more data in return on how they operate through the transportation network. This data provides insights to transportation operators helping to understand demand and assist in predicting and responding to movements around a region. This enables unprecedented opportunities to provide more responsive, efficient mobility solutions in real time and long term.

Connected and automated vehicles allow a more traveler-centric vision of MOD transportation system-of-systems by providing improved and safer mobility options, better connectivity, and real-time data.

Smart Infrastructure

Although wireless technologies, IoT, and big data all enable MOD, MOD also requires smart infrastructure particularly as connected and automated vehicles come to market. The speed and extent of the mobility innovation depends on an intelligent infrastructure.

Smart infrastructure, with ICT at its core, is the integration of sensors, networked communications, and computing hardware and software into physical infrastructure (Volpe Center, 2014). Two key enablers of smart infrastructure are:

1. *Smart Objects:* Sensors powered by high computing power and data storage have enabled data collection from almost any object in real time providing any necessary information. For example, there was growing demand for applications that allow farmers to monitor crop and field conditions, fertilizer application, and production by exact location (Wang N. Z., 2006).
2. *M2M Communication:* M2M communication is any technology that enables networked devices to exchange information and is often used for remote monitoring. M2M communication forms the basis of IoT.

Infrastructure—from bridges to streetlights—that were previously "passive" are becoming controllable or self-controlling, imbued with analytic ability to communicate with other infrastructure elements and people (Lohr, 2011). Because smart infrastructure components are connected to the Internet, they can often be

[8] Referring to the National Highway Traffic Safety Administration levels of automation. Level 5 is a fully-autonomous system that expects the vehicle's performance to equal that of a human driver, in every driving scenario.

made to work together—to collect multi-source, contextual data, and carry out integrated functions (Wasik, 2013).

In transportation, smart infrastructure ranges from roadside units that can communicate with vehicles on the road to sensors and intelligent traffic lights that constantly monitor network performance. Other examples include raised pavement markers (e.g., reflective dots) and pavement markers (studs) that incorporate LEDs able to detect vehicles and pedestrians at intersections and illuminate to alert safety hazards. Smart infrastructure with its control system elements enable a multimodal prioritization of people and goods movement. Smart infrastructure facilitates coordination among different components of the transportation network, providing safety and operational enhancements.

Information and Communications Technology (ICT)

ICT with its role in unifying communications (i.e. integration of telecommunications, enterprise software, storage, and audio-visual system) has enabled people to access, store, transmit, and manipulate a considerable amount of information. This unification has enabled radical changes in many sectors of the industry, including transportation. ICT has enabled demand responsive transport, intelligent payment systems, shared mobility, and a more integrated transportation network.

As ICT continues to evolve, the subject of inclusive ICT (i.e. removing barriers to accessing Information and Communication Technologies by persons with disabilities) has also gained more attention. A growing number of mainstream, everyday ICT such as mobile devices and desktop computers increasingly offer functionalities that facilitate communication and information access for persons with disabilities. Features such as text-to-speech and voice recognition, ability to change contrast and color schemes, touch and gesture input, and screen magnification which in the past required specialized standalone software and hardware are embedded within off-the-shelf ICT devices. Digital technologies enable persons with disabilities to receive information and content in the format that they can perceive and prefer (Raja, 2016).

The adaptation, operationalization, and implementation of ICT for inclusive development remains dependent on others factors within the ecosystem (Samant, 2013). Existing evidence shows that the success of using the internet and ICT for the inclusion of persons with disabilities is heavily impacted by stakeholders' knowledge and awareness of the ICT solutions available, laws and policies, and the capacity of various stakeholders to support accessible ICT services (Samant, 2013) (Raja, 2016).

ICT will continue to play a key role in MOD and enabling a more connected transportation network. Inclusive ICT could further enable the "transportation for all" vision providing access to all forms of mobility for everyone.

Universal Design

Universal design is the conscious and systematic effort to proactively apply principles, methods, and tools to promote a "design for all" approach in computer-related technologies, including Internet-based technologies, thus avoiding the need for specialized design (Stephanidis, (Ed.) Lawrence Erlbaum Associates, 2009). Universal design enables human diversity, social inclusion, and equality (Wikipedia, n.d.). It enables a user-centered approach to develop products that can address different human abilities, skills, requirements, and preferences.

Having a standard universal design maximizes the applicability of a technical solution to the needs of all user groups. This is especially important in addressing the needs of all travelers in a transportation system. Universal design could address some of the challenges in MOD, including accessibility issues, enabling all users (including people with disabilities and older adults) to benefit from MOD advances.

Mobile Devices and Apps

A Pew Research study found that as of April 2015, 64 percent of American adults owned a smartphone. This study found that 19 percent of American adults either do not have broadband access at home or have relatively few options for getting online other than their mobile devices (Smith, 2015). As of April 2015, the study found that 25 percent of mobile phone users occasionally received real-time public transit information using their devices; 10 percent accessed public transit information from their devices regularly. The study also found that 11 percent of users occasionally and 4 percent frequently accessed a taxi or car service from their mobile devices (Shaheen S. , Cohen, Zohdy, & Kock, 2016).

The increasing availability, capability, and affordability of ITS, GPS, wireless, and cloud technologies coupled with the growth of data availability and data sharing are causing people to increasingly use smartphone transportation apps to meet their mobility needs (Shaheen S. , Cohen, Zohdy, & Kock, 2016). Travel time savings (e.g., high occupancy vehicle lanes available to users of dynamic ridesharing), financial savings (e.g., dynamic pricing providing discounts for peak and off-peak travel and for choosing low-volume routes), incentives (e.g., offering points, discounts, or lotteries), and gamification (e.g., use of game design elements in a non-game context) are among the key factors driving end-user growth of smartphone transportation applications (Deterding, Sicart, Nacke, & O'Hara, 2011), (Marczewski, 2012).

There are four types of transportation apps that are in widespread use today (Shaheen S. , Cohen, Zohdy, & Kock, 2016):

- **Mobility Apps**: Apps that are mobility focused and include derivatives such as B2C sharing apps, mobility trackers, P2P sharing apps, public transit apps, real-time information apps, ridesourcing/TNC apps, taxi e-Hail apps, and trip aggregator apps.
- **Vehicle Connectivity Apps**: Apps that help users to connect to their vehicles remotely; these apps can be very beneficial in case of lockouts or a crash.
- **Smart Parking Apps**: Apps that make the parking process more efficient by highlighting the real-time availability and parking cost. Additionally, smart parking apps enable ease of payment. Valet parking apps allow the user to hire an experienced valet to park their vehicle after dropping it off at a convenient location.
- **CNS Apps**: Apps that provide for-hire delivery services for monetary compensation using an online application or platform (such as a website or smartphone app) to connect couriers using their personal vehicles, bicycles, or scooters with goods (e.g., packages, food).

Additionally, there are three categories of non-transportation apps that deploy strategies that may be useful for future transportation apps. These three categories of apps may encourage active modes (e.g., cycling and walking), increase environmental awareness, and impact the ways in which people drive. The categories include (Shaheen S. , Cohen, Zohdy, & Kock, 2016):

- **Health Apps**: Apps that assist users in monitoring their health (e.g., calories burned, heart rate); understanding the health impacts of their transportation choices; and encouraging health-conscious behavior, such as walking and biking. Outside of mobility, health apps are integrating health records, providing low-cost medical care, and creating motivational communities focused on health.
- **Environment/Energy Consumption Apps:** Apps that track environmental impacts and energy consumption of travel behavior (e.g., greenhouse gas emissions associated with different modal choices). Outside of mobility, environment/energy apps are reducing material consumption, connecting consumers to the environment, and generating awareness of important environmental issues.
- **Insurance Apps:** Apps that enable users to opt for pay-per-mile automobile insurance (e.g., Metromile) and other usage-based pricing and incentives related to distance, time of travel, and safe driving (e.g., Allstate's usage-based insurance app). Outside of mobility, insurance apps are speeding the insurance claims process and reducing insurance fraud.

Smartphone apps have a strong influence on the travel choices people make. Smartphone apps (and in particular, transportation apps) often deploy psychological, cognitive, emotional, and social mechanisms to influence our economic and non-economic decision making.

Connected Travelers

Connected travelers includes both people and vehicles that exchange data among themselves and other parts of transportation infrastructure. Improvements in data speed and availability are contributing to connectivity among travelers. People who have grown up with computers and the Internet—often termed "digital natives"—make up an increasing proportion of the workforce and society at large (Volpe Center, 2014). Because they are more comfortable with ICT, they tend to accept and even expect its integration into their lives (Wang Q. C., 2008). Other enablers of connected travelers are:

- Wireless communications technologies are creating a field of data connectivity among travelers and infrastructure.
- Wide usage of smartphones, mobile computing technologies, and artificial intelligence are making it easier to interface between the data-based system and the physical world.
- Big Data—a term for a family of techniques and technologies to improve and streamline any business practices—is improving the management and analysis of connected transportation data. A fully developed connected vehicle environment can produce vast amounts of information as vehicles and infrastructure send messages to one another, potentially transforming the transportation industry (Volpe Center, 2014).
- Crowdsourcing refers to "the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers" (Dictionary, n.d.). For example, Waze relies on voluntary user inputs—crowdsourced data—to generate real-time traffic alerts, route suggestions, and estimated times of arrival (Volpe Center, 2014). Crowdsourcing is another way that connected travelers can interact with the transportation network.
- Gamification refers to "the application of game design principles to non-game activities, incentivizing user engagement by appealing to a sense of fun and competition. Gamification facilitates knowledge generation process by encouraging broad user participation in activities that generate useful data at low cost. It can also be valuable in encouraging people to act in a way that advances the goals of a company or government agency. For example, transportation

agencies may be able to use gamification to actively respond to traveler demand and affect their choices" (Volpe Center, 2014). As noted previously, smartphone apps frequently leverage gamification to encourage or discourage particular traveler behaviors.

MOD Data Management

While mobile technologies and a sensor-enabled transportation system are core enablers of MOD, data management is equally critical. MOD suppliers, public transit operators, planners, and researchers need data to understand changes in the movement of people and goods and where policy intervention may be needed. While the current decentralized data sharing and management practices have been an integral component of MOD's success, the growth and mainstreaming of MOD necessitates a more organized strategy around data sharing and management.

The data management and sharing strategy for the MOD program will be informed by the large Enterprise Data Program Category within the *ITS Strategic Plan, 2015-2019* and more specifically, the enterprise data management plan. This data management plan in part states that:

> With increased connectivity among vehicles, organizations, systems, and people, unprecedented amounts of data are being generated. New methods to collect, transmit/transport, sort, store, share, aggregate, fuse, analyze, and apply these data will be needed for management and operations of transportation systems. Enterprise data management initiatives focus on enabling effective data capture from ITS-enabled technologies, including CVs (automobiles, transit, and commercial vehicles), mobile devices, and infrastructure in ways that protect the privacy of users. These activities also focus on enhancing the creation of data environments that enable integration of data from multiple sources for use in transportation research, management, and performance measurement.

In applying this plan to the MOD program, a comprehensive understanding of the program's mission, components, and goals is needed. Understanding the MOD marketplace and ecosystem will enable the effective integration of the ITS JPO enterprise data management plan with MOD. More importantly, it will enable the data that is generated to support the growth and mainstreaming of MOD.

Additionally, the integration of the ITS JPO enterprise data management plan with MOD will be mutually beneficial to both the MOD program and other programs and initiatives within the USDOT.

Data Management Plan Considerations

An enterprise data management plan touches on all aspects of the data lifecycle, from data generation to transmission, storage, sharing, and everything in between. While this section does not provide all the details associated with each aspect of the data lifecycle, it aims to provide guiding principles for a data management plan, that when followed, supports the mission of the MOD program.

Informed by the ITS JPO enterprise data management plan, the center of the MOD data management plan is its adherence to the core principles of the data management lifecycle and its components, which include:

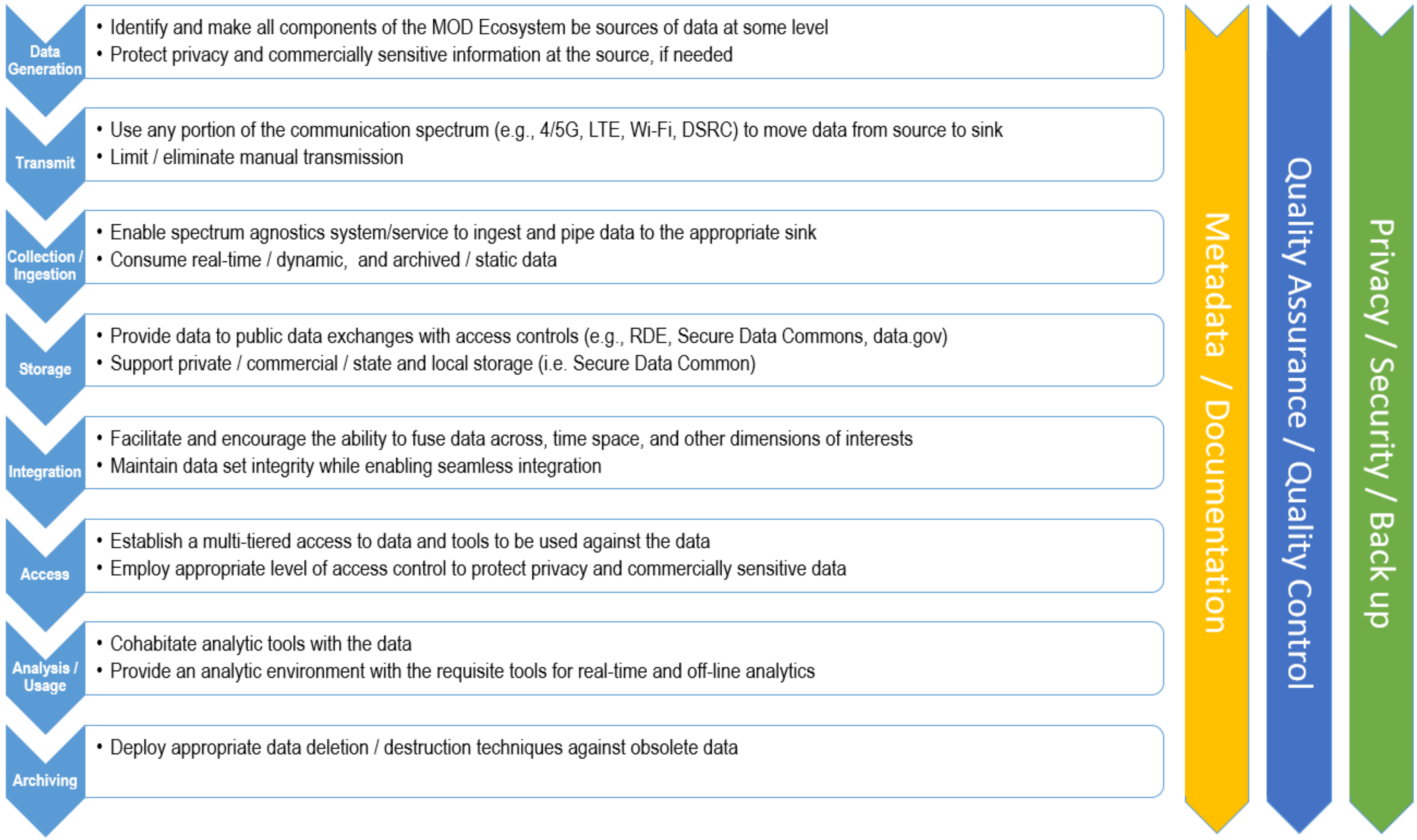
- Data Generation
- Transmission

- Collection
- Storage
- Integration
- Access
- Analysis/Usage
- Archiving.

These components map closely to the data journey. By managing data according to these points along the data journey, the data management plan is positioned to enable that data to effectively support the mission of the MOD program, as well as others looking to use the data generated by the MOD program. The plan should also include three governing features that support the data journey from source to sync. These three features are:

- Meta data/Documentation
- Quality Assurance/Quality Control
- Privacy/Security/Back-up.

Figure 12 presents, at a high level, the key components of this data management plan from the perspective of the data journey and the three governing features.



Source: USDOT, August 2017

Figure 12: Data Management Plan Components

Beyond the MOD Data Management Plan and the ITS JPO Secure Data Commons

Data sharing among the MOD stakeholders is a primary challenge that could limit its growth. While the growth of MOD has been reliant on each actor leveraging its own data and integrating it with open data sources, this will eventually limit the overall growth of MOD. Opening data for all can create a network effect allowing for capacity to be more efficiently managed and providing end users with more modal options.

A key challenge is opening and sharing data, while protecting proprietary information. To address this challenge, data stakeholders should consider:

- Who should contribute data?
- How does one contribute data to the effort while protecting proprietary information?
- How much data should be shared?
- Who should have access to the data?
- How will data be accessed?
- Should data sharing be required as a condition to access the data commons?

These and other questions will need to be addressed to enable data sharing across marketplace participants. The Airline Origin and Destination Survey (DB1B) may offer one model for data sharing. This survey requires 10 percent of airline ticket sales from reporting carriers to be collected by the Office of Airline Information of the Bureau of Transportation Statistics. Data includes origin, destination, and other itinerary details of passengers transported. This database is used to determine air traffic patterns, air carrier market shares, and passenger flows. These data have not only been instrumental to the airline industry, but also to academia and other relevant industries. A similar framework could be implemented for MOD services.

Key Takeaways

The key takeaways include:

- Internet-based platforms, ICT, location-based services, and big data are contributing to the growth of MOD.
- The emergence of connected vehicles, automated vehicles, and smart infrastructure will continue to impact MOD. Data sharing and management will be integral not only to the growth of MOD but to the continued advancement of connected, automated, and other IoT applications.

Chapter 8. Performance Measures

Innovations in MOD have the potential to impact travel patterns, vehicle ownership, and land use. Industry benchmarks and performance indicators can be an important tool to monitor MOD growth and performance, guide public policy, and develop future research agendas. Benchmarks and performance measurements are reference points that allow comparisons to be made, both as a snapshot in time and to measure longitudinal trends over time. Industry benchmarks are intended to track the size, growth, and key impacts of the industry.

The MOD program is designed to push the boundaries of public transportation by experimenting with the integration of innovative business models and advanced technologies. The goal of these initiatives is to enhance efficiency and mobility. Performance indicators allow the USDOT to measure progress toward these goals.

Table 18 includes a list of recommended performance indicators for MOD that address a wide array of issues such as economic, safety, congestion, roadway demand, level of service, public transit ridership, transit accessibility, infrastructure use, modal share, and the environment. Broadly, performance metrics should be comparable with other modes (where applicable) for effective multimodal comparisons across the transportation network.

Table 18: MOD Performance Indicators and Measurements (Examples)

Category	Performance Indicator	Measurement
Safety	• Have vehicle crashes declined? • Have bicycle crashes declined? • Have pedestrian crashes declined? • Have vehicle injuries and fatalities declined? • Have bicycle injuries and fatalities declined? • Have pedestrian injuries and fatalities declined?	• Crashes per million VMT • Crashes per 1,000 cyclists • Crashes per 1,000 pedestrians • Injuries/fatalities per million VMT • Injuries/fatalities per 100,000 cyclists • Injuries/fatalities per 100,000 pedestrians • Percentage of travelers who feel safe from crime while waiting for public transportation vehicles to arrive • Percentage of travelers who feel safe from crime while traveling in public transportation vehicles
Congestion	• Is congestion getting worse? • Are fewer people driving to work alone?	• Roadway/Intersection Level of Service (LOS) • Travel time to work (minutes) • Average vehicle occupancy

Category	Performance Indicator	Measurement
Economic Efficiency	• Are transportation users paying the full cost of using the transportation network? • If not, what is the level of public subsidy and how is this subsidy changing over time?	• Public transit farebox recovery ratio • Public transit operational cost per passenger mile/trip • Public transit operational subsidy per passenger mile/trip • MOD operational subsidy per passenger mile/trip (by MOD mode) • Driving cost per passenger mile/trip • Driving subsidy per passenger mile/trip
Transportation Productivity	• What is the multifactor productivity of MOD services?	• Revenue per passenger mile • Goods revenue per pound mile • Output per driver hour (e.g., passengers served, packages delivered, number of trips/miles driven, etc.)
Roadway Demand	• Are more workers telecommuting? • Are people driving less? • Are people getting fewer drivers licenses? • Is there a change in overall vehicle ownership?	• Average number of telecommute days per worker; per month • Average Daily VMT Per Capita • Average Annual VMT Per Capita • Light-duty VMT per capita • VMT per employee • Average daily number of trips • Number of individuals with drivers' licenses • Number of automobiles registered per capita
Level of Service (LOS)	• Is the transportation network performing at an acceptable service level? • Is public transit performance improving?	• Roadway/Intersection LOS (grade A-F) • Bicycle LOS (grade A-F) • Pedestrian LOS (grade A-F) • Number of households within 5 miles of a park-and-ride facility • Frequency of public transit service • Degree of public transit crowding (e.g., passengers per sq. ft.) • Average wait time (minutes) for a shared mode (separated by mode) • Average wait time between transfers (minutes)
Public Transit Ridership	• Is public transit ridership increasing? • Is public transit service available for travelers at all hours?	• Modal split by location and time of day • Ratio of average public transportation journey time at 8am to noon on the average weekday • Ratio of average public transportation journey time at noon on the average weekend day to the journey time at noon on the average weekday

Category	Performance Indicator	Measurement
Public Transit Accessibility	• Are people able to reach destinations using public transportation?	• Number of jobs/residents/trip origins/trip destinations within ¼-mile radius of a public transit stop • Number of households within a 30-minute public transit ride of major employment centers • Percent of population with access to 100,000+ jobs within 45-minute public transit ride • Number of households within 5 miles of a major public transit center • Percent employment/population within 1/4 mile of a public transit stop • Percentage of work and education trips accessible in less than 30-minute public transit travel time • Percentage of workforce that can reach their workplace by public transit within one hour with no more than one transfer
Destination Accessibility	• Is comparable destination accessibility available across all modes?	• Ratio of average 30-minute household travel shed via wheelchair accessible public transportation to average 30-minute household travel shed by SOV • Ratio of average 30-minute household travel shed for the cost of a typical public transportation fare to average 30-minute household travel shed by SOV • Ratio of average 30-minute household travel shed by bicycle via dedicated bike lanes (or better) to average 30-minute household travel shed by SOV
Infrastructure Use Efficiency	• Is the transportation network operating efficiently?	• Private vehicles: average vehicle occupancy • Public transit: average capacity usage rate per vehicle; average weekday vehicle boardings per vehicle revenue hour; average vehicle boardings per vehicle revenue mile; average annual transit boardings per route mile; passenger miles traveled per vehicle revenue mile • Ridesourcing, Taxis: average vehicle occupancy (excluding driver) • Carsharing: average vehicle occupancy

Category	Performance Indicator	Measurement
Modal Share	• How are people traveling?	• SOV mode share (SOV trips divided by total trips) • Multi-occupant vehicle (MOV) mode share (MOV trips divided by total trips) • Bicycle mode share (bicycle trips divided by total trips) • Pedestrian mode share (pedestrian trips divided by total trips) • Single occupant carsharing (SOC) mode share (SOC trips divided by total trips) • Multi-occupant carsharing (MOC) mode share (MOC trips divided by total trips) • Single passenger taxi/ridesourcing (SPTR) mode share (SPTR trips divided by total trips) • Multi-passenger taxi/ridesourcing (MPTR) mode share (MPTR trips divided by total trips) • Bikesharing mode share (bikesharing trips divided by total trips) • Single occupant scooter sharing (SOSS) mode share (SOSS trips divided by total trips) • Two passenger scooter sharing (TPSS) mode share (TPSS divided by total trips)
Energy Efficiency	• Is society achieving optimal energy efficiency in the transportation system?	• Total transportation carbon dioxide (CO2) emissions per capita • Total transportation CO2 emissions per household • Passenger transportation CO2 emissions per capita • Passenger transportation CO2 emissions per household • Heavy-duty vehicle CO2 emissions per capita • Heavy-duty vehicle CO2 emissions per household • Carbon dioxide equivalent (CO2eq) emissions per passenger mile traveled (passenger movement) • Co2eq emissions per ton-mile traveled (goods movement) • CO2eq emissions per passenger trip • CO2eq emissions per goods delivery trip

Category	Performance Indicator	Measurement
Land Use	• Are households living in locations with mixed land uses? • Is raw land being consumed by new transportation infrastructure and/or new development served by new transportation infrastructure?	• Ratio of jobs to housing (employment-to-dwelling unit ratio) • Acreage of undeveloped or farmland taken for new transportation infrastructure • Number of residential units and square feet of non-residential structures built on undeveloped land or farmland • Number of lane miles of roadways constructed on undeveloped land and farmland • Amount of new housing units and jobs added in formerly undeveloped land and farmland • Acres of land consumed per residential unit • Acres of undeveloped land or farmland converted to development
Affordability	• Is transportation affordable?	• Percent of annual household income spent on transportation • Average cost per mile • Average cost per mile (by mode) • Average cost per trip • Average cost per trip (by mode)

Equity	• Is the transportation network equitable?	• Average distance from the nearest public transit stop (or MOD stop) for people with disabilities and older adults • Average headway for public transit (or MOD fixed-route service at the nearest public transit (or MOD stop) for people with disabilities and older adults • Average trip time for people with disabilities compared to the entire population for like trips • Average trip time for older adults compared to the entire population for like trips • Average wait time for pickup for people with disabilities compared to the entire population for like trips • Average wait time for pickup of older adults compared to the entire population for like trips • Average per mile and trip costs for people with disabilities compared to the entire population for like trips • Average per mile and trip costs for older adults compared to the entire population for like trips • Number of jobs accessible within 1 hour of travel time by income group • Access to healthcare facilities by income group • Access to educational facilities by income group • Access to recreational facilities by income group • Access to healthy food by income group • Average work trip travel time by income group • Average non-work trip travel time by income group • Average travel time to key destinations by income group • Average travel time to major activity/employment centers by income group • Average distance to the nearest public transit stop by income group • Average distance to the nearest shared mode (separated by mode) • Availability of nighttime public transit service • Availability of nighttime shared modes (separated by mode) • Availability of low-cost public transit options (e.g., less than $3 per trip) • Availability of low-cost shared mobility options (e.g., less than $3 per trip) • Percentage of bus stops with shelters • Percentage of bus stops with real-time information sources

Category	Performance Indicator	Measurement
		• Average taxi/ridesourcing wait time by gender • Percentage of canceled taxi/ridesourcing rides by gender • Average taxi/ridesourcing wait time by race/ethnicity • Percentage of canceled taxi/ridesourcing rides by race/ethnicity • Average taxi/ridesourcing wait time for people with disabilities • Percentage of canceled taxi/ridesourcing rides for people with disabilities
Smartphone/ Mobile Apps	• How are travelers using technology?	• Percentage of population with access to a smartphone • Percentage of population with access to high-speed mobile Internet • Percentage of non-auto trips booked using a mobile app • Percentage non-auto trips paid using a mobile app
Customer Satisfaction	• Is the transportation service satisfactory to the users? • Is the service provided reliable? • How easy it is to make payments? • What's the level of productivity of the customers? • How comfortable is the ride?	• Customer satisfaction for each mode • Availability of comparison of modes by cost and by time via an integrated trip planning platform • Ability for customers to provide feedback on public transportation trips in real-time • Existence of opt-in alert system for service changes • Ability to plan wheelchair accessible trips, including with real-time elevator service and vehicle accessibility information if relevant • Existence of physical wayfinding information that is accessible to all • Existence of integrated fare payment media / account-based payment • Existence of payment methods for unbanked travelers • Percentage of traveler waiting-minutes spent at stations with cell phone service and/or WiFi • Estimated percentage of traveler trips taken for which no seats are available

Key Takeaways

The key takeaways include:

- Performance measures should be used as a measure of whether public policy goals are being achieved.
- The performance measures, if used strategically, should identify whether improvements and progress have been made in improving safety, mobility, affordability, accessibility, and other key policy goals.
- Performance metrics should be comparable with other modes (where applicable) for effective multimodal comparisons across the transportation network.

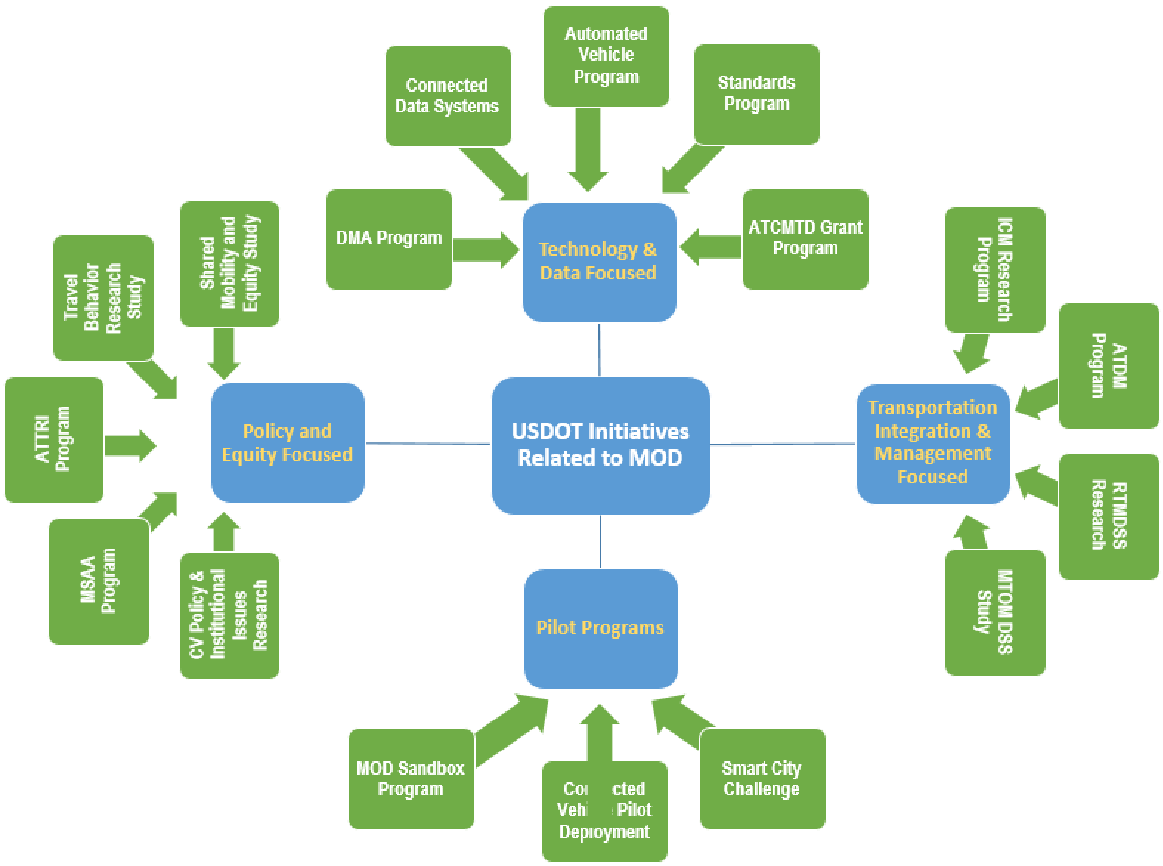
Chapter 9. MOD Programs within the USDOT and Other Agencies

This chapter outlines some of the key programs and initiatives that have important contribution to the MOD evolution within the USDOT and other federal agencies.

MOD-Related Initiatives with the USDOT

Several programs and initiatives within the USDOT are important to the mission and vision of MOD. These initiatives are categorized into four groups (see Figure 13):

1) Technology and data focused initiatives that leverage existing technologies to help with advancement of the vision of MOD.
2) Transportation integration and operations management initiatives that integrate different transportation systems to more efficiently and effectively manage operations.
3) Policy-focused initiatives that tend to focus on environmental justice and equity goals.
4) Pilot programs that test technologies and proofs of concept (e.g., MOD sandbox program).



Source: USDOT, August 2017

Figure 13: USDOT Initiatives that Contribute to the Vision, Mission, and Evolution of MOD

Technology-Focused Initiatives

ITS JPO Dynamic Mobility Applications Program (DMA)

The objective of the DMA research program is to identify transformative applications and innovative methods to manage and operate transportation systems based on the availability of new data sources and communications methods. Moreover, the program aims to build an application data integration platform foundation that will transform the data into information that can provide travelers and systems operators with greater access to real-time information about the transportation system to better enhance decision making. Through this program, the ITS JPO has sponsored research and development on six high-priority transformative mobility application bundles:

- Enable Advanced Traveler Information System (EnableATIS)
- Freight Advanced Traveler Information Systems (FRATIS)
- Integrated Dynamic Transit Operation (IDTO)
- Intelligent Network Flow Optimization (INFLO)

- Multimodal Intelligent Traffic Signal Systems (MMITSS)
- Response, Emergency Staging and Communications, Uniform Management, and Evacuation (R.E.S.C.U.M.E).

Each bundle contains a set of related applications that focus on similar outcomes (i.e., more efficient signal prioritization and timing for mobility), but perform in different capacities (i.e., transit signal priority versus emergency preemption). Importantly, each application could not work as effectively without understanding the influence of integrating with other applications—the timeframe that they have to operate (sometimes within seconds), and the nature of the impacts and need to sequence the impacts are highly related.

The following expands on some of the key applications of the DMA program that are more relevant to the objective of MOD—namely EnableATIS, FRATIS, and IDTO.

EnableATIS: The aim of EnableATIS is to develop a suite of capabilities to foster multisource data integration and delivery; promote development of dynamic, real-time multimodal traveler information and applications; improve transportation system mobility and safety; and advance research with new forms of data about traveler behavior and response to transportation operations. While no specific applications are being developed under EnableATIS, activities include expanding and exercising emerging data sets that merge multimodal data into potentially transformative traveler information, and exploring ways of increasing data collection as well as capturing traveler behavior through nomadic platforms.

FRATIS: FRATIS is a logistics technology aimed at improving freight operational efficiency. While there are many advanced traveler information systems (ATIS) geared toward passenger travel, freight has unique operational characteristics that require different data and methods/timeframes of information delivery. Two of the key applications under this bundle are Freight Dynamic Route Guidance and Drayage Optimization (Jensen, et al., 2012).

The Freight-Specific Dynamic Travel Planning and Performance application will include all of the traveler information, dynamic routing, and performance monitoring elements and leverage existing data and private sector applications to benefit both the private and public sectors.

IDTO: IDTO is the public transit-specific component of the DMA program, which builds on FTA's history of adopting technology to help improve efficiencies and rider experience. IDTO blends the emerging connected vehicle concepts with advances in smartphone technology and location-based services to provide dynamic scheduling, dispatching, and routing capabilities; enable and protect multimodal and multi-agency transfers; facilitate dynamic ridesharing; and integrate these features into a single system for travelers and public transit agencies. This bundle includes three applications—T-DISP, T-CONNECT, and Dynamic Rideshare.

T-DISP (Dynamic Transit Operations) is the mobile application piece of the IDTO prototype and is used by the traveler to search for and save public transit trips in the IDTO system. T-DISP seeks to expand transportation options by leveraging available services from multiple modes of transportation. Travelers would be able to request a trip via a mobile device (smartphone or personal computer) and have itineraries containing multiple transportation services (public transportation modes, private transportation services, shared ride, walking, and biking) sent to them via the same device. T-DISP builds on existing technology systems, such as computer-aided dispatch/automatic vehicle location (CAD/AVL) systems and automated scheduling software. These systems must be expanded to incorporate business and organizational structures that aim to better coordinate transportation services in a region. A physical or virtual central system, such as a travel management coordination center (TMCC) would dynamically schedule and dispatch trips. T-DISP enhances communications with travelers and presents them with the broadest range of travel options when making a trip.

T-CONNECT (aka Connection Protection) uses a backend cloud computing platform that provides monitoring and management functions. The goal of T-CONNECT is to improve rider satisfaction and reduce expected trip time for multimodal travelers by increasing the probability of intermodal or intra-modal connections. T-CONNECT will seek to protect transfers between both transit (e.g., bus, subway, and commuter rail) and non-transit (e.g., shared ride) modes, and will facilitate coordination between multiple agencies to accomplish the tasks. In certain situations, integration with other IDTO bundle applications (T-DISP and D-RIDE) may be required to coordinate connections between public transit and non-transit modes, and between public and private transportation providers.

D-RIDE is an approach to carpooling in which drivers and riders arrange trips within a relatively short time in advance of departure. Through D-RIDE, a person could arrange daily transportation to reach a variety of destinations, including those that are not serviced by transit. D-RIDE serves as a complement subsystem within the IDTO bundle by providing an alternative to transit when it is not a feasible mode of transport or is unavailable within a certain geographic area. The D-RIDE system is envisioned to be used on a one-time, trip-by-trip basis, and would provide drivers and riders with the flexibility to make real-time transportation decisions. D-RIDE could help reduce peak demand for public transit so the public transit system can be designed more affordably and have greater customer satisfaction during peak hours.

Relevance to MOD: While focused on different elements of the transportation system, these applications contain similar characteristics that are key to the vision of MOD:

- Connectivity to enable dynamic decision making
- Capable of anticipating problems and proactively addressing issues by rapidly monitoring impacts on and across multimodal transportation networks
- Support emerging work in DSS—systems that can assimilate and analyze large volumes of detailed real-time and historic data to provide recommendations in formats that are most valuable to traffic managers or travelers
- Greater efficiencies obtained as the same data and observations can be used across all applications
- Greater safety and operational awareness of a broad range of impacts.

ITS JPO Connected Data Systems (CDS) Program

The USDOT CDS program is a key component of the Enterprise Data Program Category within the *ITS Strategic Plan, 2015-2019* (Barbaresso, et al., 2014). This enterprise data management initiative focuses on effective data capture from ITS technologies, including connected vehicles (automobiles, public transit, and commercial vehicles), mobile devices, and infrastructure in ways that protect the privacy of users; integrate data from diverse sources; and provision data for use in operations, research, and performance measurement.

The CDS program recognizes that data-related research is needed across all programs, including Connected Vehicle Pilots, Connected Automation, and Smart Connected Cities, among others. The CDS program seeks to operationalize scalable data management and delivery methods, exploiting the potential of high-volume multi-source data to enhance current operational practices and transform future surface transportation systems management.

Relevance to MOD: As discussed in Chapter 7, data is at the center of the MOD, and data collected from connected vehicles can contribute immensely to the efficiency of MOD and real-time management of the issues with the mobility system.

ITS JPO Automated Vehicle Research

The automated vehicle research aims to enable and accelerate the development and deployment of automated vehicles, ensure safe and efficient operations of emerging technologies and systems, and maximize public benefits by leveraging connected vehicle technologies, infrastructure-based solutions, and other approaches. The USDOT automation program will position industry and public agencies for the wide-scale deployment of partially automated vehicle systems that improve safety and mobility and reduce environmental impacts by the end of the decade. The goals of this program are to:

- Develop estimates of the potential benefits and costs of automated vehicles
- Evaluate and promote enabling technologies
- Develop prototype applications
- Identify needed standards and appropriate methods for development
- Identify technical, policy, institutional, and regulatory barriers to deployment and possible solutions
- Generate design guidelines for automated vehicles
- Collaborate with a broad range of public and private stakeholders.

Relevance to MOD: The advancements in automated vehicles directly impact MOD as it could make the availability of mobility options more immediate, enabling a truly on-demand service. The activities in the automated vehicle research program including prototype testing, standardization, and policy-focused efforts can inform similar activities within the MOD program.

ITS JPO Standards Program

The USDOT established the ITS Standards program in 1996 to encourage the widespread use of ITS technologies in the nation's surface transportation systems. ITS standards exist within technologies deployed under the framework of the National ITS Architecture and define how system components interconnect and interact. Because ITS standards are based on open, non-proprietary technology, they can facilitate the deployment of interoperable systems and make it easier for state and local ITS developers to deploy regionally integrated transportation systems.

The ITS Standards program is teaming with standards development organizations (SDOs) to accelerate the development and testing of nearly 100 consensus-based, ITS standards, while working with state and local highway and transit agencies on standards-based ITS implementation strategies.

The ITS Standards program undertakes a range of activities including:

- Developing standards (through cooperative agreements with SDOs) for both existing ITS technologies and connected vehicle applications. The program is also active in international efforts to harmonize ITS standards and architecture to increase commonality of connected vehicle technologies across multiple regions.

- Testing standards in actual transportation settings (through field testing by state and local transportation agencies).
- Providing technical assistance to state and local ITS developers (through ITS specialists at FHWA Resource Centers and through the ITS Field Support Team).
- Delivering ITS standards training and workshops (through training programs offered by the Institute of Transportation Engineers and the ITS Professional Capacity Building program).
- Developing experience-based deployment guidance and tools, such as lessons learned.
- Providing up-to-date information about ITS standards development, testing, deployment, and training activities (through the ITS Standards Program website).

Relevance to MOD: Standardization is an important piece of MOD. All the applications and interfaces in MOD and, particularly, the shared mobility sector should be standardized to enable smooth integration among different pieces of the system. Any standardization effort undertaken by the MOD program should occur in collaboration with the ITS Standards program as there are entry points that the two could connect and take advantage of. This is especially important as connected and automated vehicles advance, and as MOD will take advantage of these technologies.

FHWA Advanced Transportation and Congestion Management Technologies Deployment (ATCMTD) Grant Program

The Fixing America’s Surface Transportation (FAST) Act established the ATCMTD program to make competitive grants for the development of model deployment sites for large-scale installation and operation of advanced transportation technologies to improve safety, efficiency, system performance, and infrastructure return on investment. The FAST Act funds the program through a set-aside from the Highway Research and Development, Technology and Innovation Deployment, and ITS research programs. Grant recipients may use funds under this program to deploy advanced transportation and congestion management technologies, including:

- Advanced traveler information systems
- Advanced transportation management technologies
- Infrastructure maintenance, monitoring, and condition assessment
- Advanced public transportation systems
- Transportation system performance data collection, analysis, and dissemination systems
- Advanced safety systems, including vehicle-to-vehicle and vehicle-to-infrastructure communications
- Technologies associated with autonomous vehicles, and other collision avoidance technologies, including systems using cellular technology
- Integration of ITS with the Smart Grid and other energy distribution and charging systems
- Electronic pricing and payment systems
- Advanced mobility and access technologies, such as dynamic ridesharing and information systems to support human services transportation for older adults and people with disabilities.

Relevance to MOD: The insights gained from this program, particularly, in the areas of traveler information systems; transportation management technologies; data collection, analysis, and dissemination systems; dynamic ridesharing; and information systems are most relevant and valuable to the MOD program.

Transportation Operations Management and Integration Initiatives

USDOT ICM Research Program

The vision for ICM is to realize significant improvements in the movement of people and goods through aggressive and proactive management of major multimodal transportation corridors. ICM's focus is on four major strategic areas (Gonzalez, Hardesty, Hatcher, Mercer, & Waisley, 2015):

- Information sharing/distribution
- Improved operational efficiency at network junctions
- Accommodation (passive) and promotion (active) of cross-network route and modal shifts
- Management of capacity-demand relationship within a corridor in real time.

ICM requires the operational coordination of multiple transportation networks and cross-network connections comprising corridors and the institutional coordination of those agencies and entities responsible for corridor mobility. ICM is a collection of operational strategies and advanced technologies that allow transportation subsystems, managed by one or more transportation agencies, to operate in a coordinated and integrated manner. When implemented, these strategies provide potential to manage a corridor in an integrated fashion. With ICM, transportation professionals manage the transportation corridor as a multimodal system rather than taking the more traditional approach of managing individual assets.

The USDOT selected two corridors (US 75 in Dallas, TX, and I-15 in San Diego, CA) to demonstrate the nation's first ICM systems.

- The ICM Dallas demonstration site leveraged the DART data portal and the Inter-Agency Information Exchange Network to support its real-time monitoring system. The DART data portal uses multiple data sources from various components of the transportation system, such as transit and paratransit operations, emergency management systems, smart card transactions, and HOV systems. These data are consolidated in a central DART database.
- ICM San Diego leveraged the local support offered by PeMS to build its real-time monitoring system framework. PeMS, a real-time archive data management system, collects freeway lane information from sensors across several districts in California at a temporal fidelity of 20 to 30 seconds. PeMS incorporates data received from several transportation domains, such as ITS devices, toll tag data, Bluetooth-based data, and incident data. The incoming data is treated for detector diagnostics, an automated process performed nightly to determine the reliability of the sensors. PeMS uses this processed and aggregated data to calculate speed, other aggregated metrics, and performance measures.

Relevance to MOD: ICM has a data centric focus on key aspects of MOD including multimodal systems, demand management, and event response, providing an integrated solution that benefits several factions of the transportation system.

FHWA Office of Operations ATDM Program

ATDM is the dynamic management, control, and influence of travel demand, traffic demand, and traffic flow of transportation facilities. Through the use of available tools and assets, traffic flow is managed and traveler behavior is influenced in real time to achieve operational objectives, such as preventing or delaying breakdown conditions, improving safety, promoting sustainable travel modes, reducing emissions, or maximizing system efficiency. Under an ATDM approach, the transportation system is continuously monitored. Using archived data and/or predictive methods, actions are performed in real time to achieve or maintain system performance.

The ATDM program aims to support agencies and regions considering moving toward an active management approach. Through customized workshops, tools, guidance documents, resources, and peer exchanges, the program can assist with technical support to implement ATDM strategies. The program also aims to explore solutions for the dynamic management, control, and influence of travel demand, traffic demand, and traffic flow of transportation facilities. Some of the projects under this program include:

Analysis, Modeling, and Simulation (AMS) ATDM and DMA Testbed Development and Evaluation: The primary objective of this project is to develop multiple simulation testbeds/transportation models to evaluate the impacts of DMA connected vehicle applications and the active and dynamic transportation management strategies. This project seeks transformative mobility, safety, and environmental impacts through enhanced, performance-driven operational practices in surface transportation systems management. To explore a potential transformation in transportation systems performance, an AMS capability is required. AMS tools and methodologies offer a cost-effective approach to address complex questions on optimization of longer-range investments, shorter-term operational practices, and overall system performance. A joint DMA-ATDM AMS Testbed could make significant contributions in identifying the benefits of more effective, more active systems management, resulting from integrating transformative applications enabled by new data from wirelessly connected vehicles, travelers, and infrastructure (Noblis, 2016).

Smartphone Applications to Influence Travel Choices – Practices and Policies: This primer is intended to demonstrate the growing importance of mobile devices to the transportation network. The primer also provides public agencies, transportation managers, and elected officials with perspective on and understanding of the role of smartphones in identifying services and choices for individuals and influencing travel behavior. The primer provides an introduction to and overview of smartphone applications (known as apps). It discusses the background, evolution, and development of smartphone apps; reviews the types of smartphone applications promoting transportation efficiency and congestion reduction; discusses transportation apps and their impacts on traveler behavior; examines current challenges; and concludes with guiding principles for public agencies (Shaheen S. , Cohen, Zohdy, & Kock, 2016).

Shared Mobility: Current Practices and Guiding Principles: This primer aggregates findings from numerous shared mobility resources and provides a reference to aid public policy development. It provides an introduction and background to shared mobility; discusses the government's role; reviews success stories; examines challenges, lessons learned, and proposed solutions; and concludes with guiding principles for public agencies. The primer provides an overview of this emerging field and current understanding. This primer is intended for individuals, public agencies, and communities who want to know more about shared mobility and communities interested in incorporating shared mobility into their transportation networks. This report offers a practical guide with resources, information, and tools for local governments and public agencies seeking to implement emerging services or to manage existing shared mobility services (Shaheen, Cohen, & Zohdy, 2016).

Relevance to MOD: The ATDM program and its focus on travel demand, traffic demand, and traffic flow of transportation is at the center of MOD. MOD is disrupting the trip chain and consequently affecting travel demand and traffic flow, which should be further studied in concert with the ATDM objectives. The studies conducted under ATDM (i.e., AMS, Shared Mobility primer and Smartphone Applications) are key research that work as the fundamentals for any follow-up research in MOD. In fact, the shared mobility and smartphone primers are the references that were used extensively in this operational concept report.

Real-Time Multimodal Decision Support System (RTMDSS) Research

The USDOT's research on the RTMDSS concept was part of a broader effort to find ways to transform transportation management and operations by utilizing connected vehicle data. This work was completed in June 2011, producing a Scan of Current Practices in DSS Capability; a Gap Analysis and Identification of Research Opportunities; a Concept of Operations; and an Assessment of Functional, System and Data Requirements.

RTMDSS can be defined as an interactive, software-intensive system that gathers and processes data from multiple sources to support decision-making for multimodal transportation operations. It uses data, models, and other analytical processes to make real-time recommendations to assist in managing a multimodal transportation network—with the ultimate goals of increasing system efficiency and improving individual mobility, providing safe, reliable, and secure movement of goods and people.

RTMDSS includes a centralized management system that serves as the hub of a greatly expanded network of data flows. RTMDSS also elevates information-gathering, goal-setting, and decision-making beyond the corridor-level, to the urban or regional level. Finally, RTMDSS incorporates connected vehicle technologies, and lays out specific frameworks for many of the data flows required for managing a multimodal transportation operation including data inputs from transportation system managers, mobility providers, freight operators, parking systems, emergency management, individual vehicles, and infrastructure among others.

No further work has been done on RTMDSS, although it has informed other research such as the Multimodal Transportation Operations Management (MTOM) DSS Research Study.

Relevance to MOD: With its focus on multimodal transportation operations, this research is important for the MTOM DSS piece of the MOD ecosystem. This is where the USDOT can affect and provide feedback to the MOD ecosystem. A data-centric approach of RTMDSS aligns with the goals of the MOD program. Any focus in this area by the MOD program should be built on the RTMDSS research.

MTOM DSS Research Study

This is envisioned to be foundational research to support decisions by the USDOT ITS JPO and their USDOT modal and other partners about investing in MTOM DSS research. The USDOT is preparing a technical memorandum that outlines a concept for regional, multimodal, and highly dynamic integrated surface transportation system management, which responds to recent and anticipated trends, opportunities, and challenges such as the emergence of new forms of mobility (e.g., Uber, Lyft). The concept report provides an architecture for the multimodal mobility ecosystem, which includes transportation operators as a system element. MOD providers are included within this element and have their role within the ecosystem articulated. Major elements of 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
- 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.

Relevance to MOD: This study could directly feed into better establishing the vision of the MOD program and determine how it can influence the MOD ecosystem.

Policy and Equity-Focused Initiatives

ITS JPO Connected Vehicle Policy and Institutional Issues Research Program

The objective of the ITS Policy and Institutional Issues research program is to identify and analyze solutions for critical policy and institutional issues that may hinder or present challenges to successful deployment of new and emerging technologies, applications, and systems that are anticipated to have a transformative impact on transportation and offer significant public benefits. An overarching focus of the program's efforts is the creation of policy and institutional models associated with successful technology transfer, adoption, implementation, and use across critical areas of ITS research. The current policy research agenda focuses on:

- Security policy for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) systems
- Implementation analysis for V2V and V2I, including DMA, Data Capture and Management, and Applications for the Environment: Real-Time Information Synthesis
- Communications analysis and spectrum policy
- Interoperability and standards policy
- Data access and use
- Automation
- Emerging capabilities
- Policy development and exchanges with international partners.

Relevance to MOD: There are many overlaps between this policy research program and any MOD-related policy work necessary, including aspects such as data security, interoperability and standards policies, and policy harmonization efforts.

ITS JPO and FTA Mobility Services for All Americans (MSAA) Program

The USDOT MSAA program aims to provide a coordinated effort and apply technological solutions to barriers experienced in accessibility and mobility for the transportation disadvantaged. The MSAA program was launched by the USDOT in 2005 after a Presidential Executive Order on Human Service Transportation Coordination (Executive Order 13330) established the Interagency Transportation Coordinating Council on Access and Mobility (CCAM) to enhance accessibility and mobility for persons who are transportation disadvantaged. Currently, MSAA supports the work of the CCAM by seeking to increase mobility and access to transportation for all Americans and to achieve more efficient use of Federal transportation funding and resources.

Through the MSAA program, the USDOT intends to improve transportation services and access to employment, healthcare, education, recreation, social activities, and other community activities through a coordinated effort enabled by various ITS technologies and applications. Researchers are working on ways to integrate ITS technologies into a physical or virtual TMCC that networks all the local transit, human service transportation (HST), paratransit, and other mobility services by non-profit or private providers through ITS technologies. Those integrative technologies allow the participating agencies/organizations to share data and resources such as schedules, trip itineraries, AVL information, and call center and dispatching, as well as user-defined passenger credentials for fare qualification.

Through the MSAA, the USDOT fosters partnerships among paratransit service providers; local governments; and other public, private, and non-profit assistance organizations to share data and better manage resources to improve mobility options for everyone. Additionally, the MSAA research environment provides an opportunity to test new ways to align and share assets across organizations and remove institutional barriers through coordinated planning and deployment.

Embracing the notions of institutional coordination and cooperation alongside technology integration, initial phases of MSAA adopted a five-phased approach with two embedded go/no-go decision points to advance the quality and efficiency of HST delivery. These five phases were: 1) coalition building, 2) foundational research, 3) planning and design of ITS-enhanced HST, 4) deployment and evaluation of ITS-enhanced HST models, and 5) documentation and outreach.

MSAA has provided a platform that has effectively raised stakeholder awareness and excitement about the HST coordination opportunities. Project site meetings attract active participation from state and local government decision-makers, transportation operators, human service agencies, and clients. Elected officials are attending meetings and offering their support to the MSAA teams. Industry vendors actively participate and contribute their expertise. Other involved parties include:

- Coordinating Council on Access and Mobility
- ITS JPO
- Federal Transit Administration
- U.S. Department of Health and Human Services
- National Transit Institute.

Relevance to MOD: One key aspect of MOD is the equity issue and how MOD could be expanded to benefit all Americans. The MOD program can benefit from the efforts of MSAA identifying the most critical areas to reduce the gap for all in accessing MOD.

Accessible Transportation Technologies Research Initiative (ATTRI)

ATTRI is a joint USDOT initiative, co-led by the FHWA and FTA, with support from the ITS JPO and other Federal partners.

ATTRI leads efforts to research, develop, and implement transformative solutions, applications, and systems to help all people, particularly those with disabilities, effectively plan and execute their travel, addressing individual mobility needs. The initiative will enhance the capability of travelers to reliably, safely, and independently accomplish their unique travel plans.

Complete Trip

The accessibility of a transportation system can be described in terms of the ability of individuals to go from home to a destination without breaks or in terms of a complete trip with various links such as trip planning, travel to station, station/stop use, boarding vehicles, using vehicles, leaving vehicles, using the stop or transferring, and travel to destination after leaving the station or stop. If one link is not accessible, then access to a subsequent link is unattainable and the trip cannot be completed. Thus, the complete trip defines the scope of potential research and development in accessible transportation. The inability to get to and from destinations, i.e., from home to a transit station and from the station to a final destination (the *first mile/last mile* problem) and distance traveled are persistent problems in the complete trip. An accessible trip allows individuals with disabilities, especially those with severe disabilities, to have independent access to work sites, educational programs, health facilities, and social and recreational activities

ATTRI leverages recent advances in vehicle automation, infrastructure, and pedestrian-based technologies, as well as accessible data, mobile computing, robotics, artificial intelligence, object detection, and navigation. These technologies are enabled by ever-present wireless communications that connect travelers and their mobile devices, vehicles, and roadside infrastructure. The technologies used by ATTRI provide almost ubiquitous access to a wealth of real-time situational data sources, including data specific to transportation, municipalities, and points of interest; crowd-sourced information; and accessibility data.

ATTRI seeks to remove barriers to transportation by leveraging advanced technology to enable people to travel independently—any time, to any place, regardless of their individual abilities. ATTRI supports the development of applications that will result in an efficient and affordable transportation system that allows individuals with disabilities and all travelers to reliably, safely, and independently plan and execute seamless travel from origin to destination. The program partners with other federal agencies (including the National Institute on Disability, Independent Living and Rehabilitation Research and the DOL Office of Disability Employment Policy, Interagency Committee on Disability Research) to research, develop, and implement transformative solutions, applications, and systems to help all people, particularly those with disabilities, effectively plan and execute their travel, addressing individual mobility needs.

ATTRI research focuses on the needs of three target stakeholder groups: people with disabilities, veterans with disabilities, and older adults. ATTRI research also focuses on developing applications and solutions that address the needs of four types of disabilities: vision, mobility, hearing, and cognitive. Inadequate mobility and transportation can hinder ATTRI stakeholders from completing important tasks, such as obtaining and maintaining employment, traveling to appointments, shopping for groceries, or attending social events that many take for granted.

ATTRI takes a multi-phased, iterative approach to achieving its vision of increased independent mobility for all travelers through exploratory research, prototyping and innovative solutions, and encouraging deployment through demonstrations, standards, guidance, and outreach (USDOT, n.d.).

Relevance to MOD: Accessible transportation is critical for independent living. Mobility means having transport services going where and when one wants to travel; being informed about the services; knowing how to use them; being able to use them; and having the means to pay for them. For people with mobility, sensory, or cognitive impairments, accessible mobility can have many challenges. Like the MOD program, ATTRI aims to employ advanced technologies to provide reliable transportation options for all people equitably. Furthermore, FTA funding for projects under ATTRI indicates further synergies the two programs have. Table 19 highlights commonalities of the two programs.

Table 19: Common Characteristics of MOD and ATTRI Programs

Characteristic	Description
Target Population	People with disabilities, veterans with disabilities and older adults
Technologies	Intelligent transportation systems, data integration, automated vehicles, smart phone technologies, smart city applications, IoT
Guiding Principles	Traveler centric, data connected, platform independent and mode agnostic
Multimodal in Nature	Integrated payments, multimodal trip options for ease and convenience
Partnership Driven	Embrace public private partnerships to advance development of innovative technologies
Institutional and Policy	Evaluating the institutional and policy barriers that can assist in development and implementation of innovative applications

FHWA Office of Policy Understanding Travel Behavior Research Study

The objective of this research is to provide a detailed assessment of the research on travel behavior. This study includes an integrated review of the literature on travel behavior with a special emphasis on socio-demographic factors and emerging trends in niche travel markets. The objective is to provide options to FHWA on the latest knowledge and methods to better understand and forecast the impact of population, socio-economic, geographic, and societal trends on future regional and national travel demand.

The project will also identify data gaps and data options from non-traditional sources. A review of data gaps and new methodologies was also conducted to fully assess the cost and benefits of various data options, including new data collection and data purchase.

This study creates the foundation for FHWA's future work and supports the capability to understand emerging trends that will impact the level and distribution of passenger travel.

Relevance to MOD: This study is a deeper look at socio-demographic factors and current transportation equity barriers that could directly affect MOD. The results of this research could inform future initiatives in the MOD program to close the accessibility gaps in MOD.

FHWA Office of Policy Shared Mobility and Equity Study

This research project builds on the Understanding Travel Behavior study and examines barriers inhibiting low-income usage of shared mobility services, including cultural, financial, and geographical coverage. The research will outline findings that have raised equity issues and/or covered proposed or implemented solutions that potentially address these issues in shared mobility. It will also include equity issues that may be idiosyncratic to the emerging shared modes, such as scooter sharing, micro-transit, ridesharing (e.g., carpooling, vanpooling), and CNS.

Relevance to MOD: Similar to the travel behavior study, this research is a deeper look at current transportation equity barriers within the shared mobility sector, which is an important piece of MOD. The results of this research could inform future initiatives in the MOD program to close the accessibility gaps in MOD and shared mobility.

Pilot Programs

Connected Vehicle Pilot Deployment Program

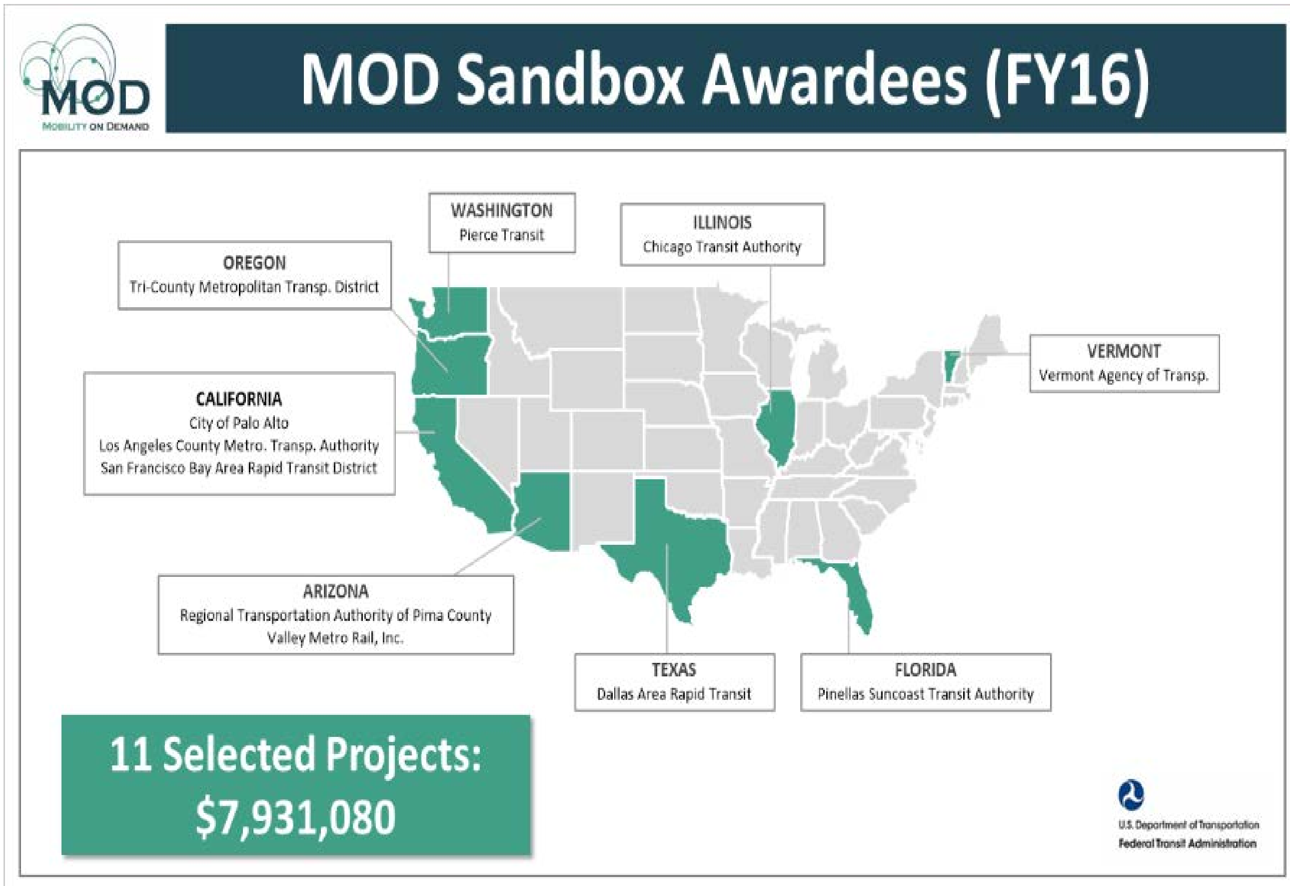
In September 2016, the USDOT awarded three cooperative agreements collectively worth more than $45 million to initiate a design/build/test phase of the Connected Vehicle Pilot Deployment Program in three sites: Wyoming, New York City, and Tampa. Sponsored by the USDOT ITS JPO, the program is a national effort to deploy, test, and operationalize cutting-edge mobile and roadside technologies and enable multiple connected vehicle applications. These innovative technologies and applications have the potential for immediate beneficial impacts. They are designed to save lives, enhance personal mobility, improve economic productivity, reduce adverse environmental impacts, and transform public agency operations.

The program seeks to spur innovation among early adopters of connected vehicle application concepts using the best available and emerging ITS and communications technologies. The pilot deployments are expected to integrate connected vehicle research concepts into practical and effective elements, enhancing existing operational capabilities. The intent of these pilot deployments is to encourage partnerships of multiple stakeholders (e.g., private companies, states, public transit agencies, commercial vehicle operators, and freight shippers) to deploy applications using data captured from multiple sources (e.g., vehicles, mobile devices, and infrastructure) across all elements of the surface transportation system (i.e., public transit, freeway, arterial, parking facilities, and tollways) to support improved system performance and enhanced performance-based management. The pilot deployments are also expected to support an impact assessment and evaluation effort that will inform a broader benefit-cost assessment of connected vehicle concepts and technologies.

Relevance to MOD: The Connected Vehicle Pilot program contribution to MOD is through its data-centric and mobile technology focused approach enabling connected travelers and improving personal mobility, energy efficiency, and integration of transportation operations.

FTA MOD Sandbox Demonstration

The FTA's MOD Sandbox Demonstration provides a venue through which integrated MOD concepts and solutions (supported through local partnerships) are demonstrated in real-world settings. Through the MOD Sandbox, FTA seeks to fund project teams to innovate, explore partnerships, develop new business models, integrate transit and MOD solutions, and investigate new enabling technical capabilities such as integrated payment systems, decision support, and incentives for traveler choices.



Source: USDOT FTA, December 2016

Figure 14: The 11 FY16 MOD Sandbox Demonstration Projects

The MOD Sandbox aims to examine issues and explore opportunities and challenges for public transportation as they relate to technology-enabled mobility services, including ways that public transit can learn from, build on, and interface with innovative transportation modes from a user, business model, technology, and policy perspective. The objectives of the sandbox include:

- Enhancing transit industry preparedness for MOD
- Assisting the transit industry to develop the ability to integrate MOD practices with existing transit services
- Validating the technical and institutional feasibility of innovative MOD business models, and documenting MOD best practices that may emerge from the demonstrations
- Measuring the impacts of MOD on travelers and transportation systems
- Examining relevant public sector and federal requirements, regulations, and policies that may support or impede transit sector adoption of MOD.

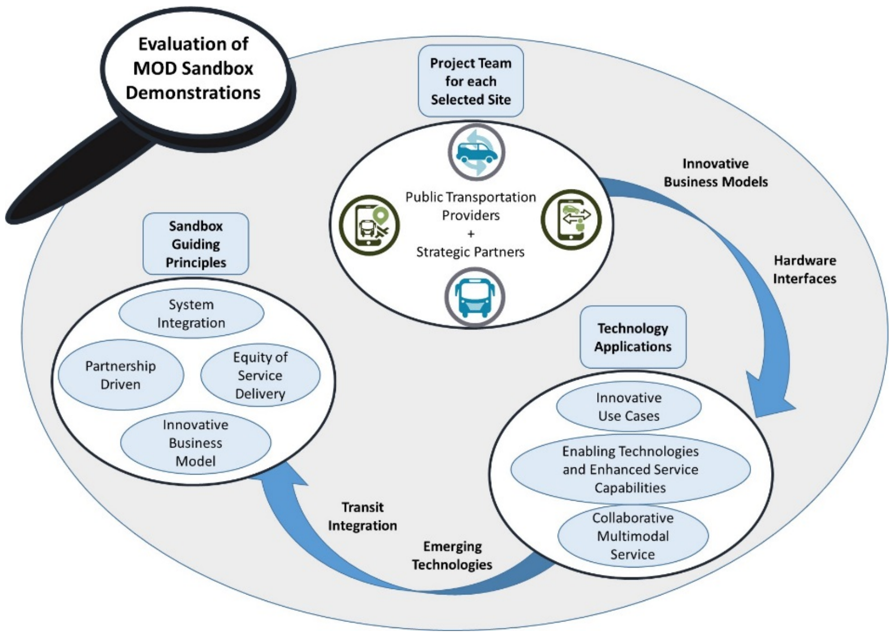
For Fiscal Year 2016 (FY16), FTA announced 11 MOD Sandbox awardees (see Figure 14 for a map and Table 20 for a description of each pilot program). The funds are used to research, demonstrate, and design projects that merge public transit and MOD concepts. Most the funding is going toward the development of some type of application or passenger information tool that will allow users to better connect transit and mobility options. This includes several projects that will attempt some form of payment convergence.

Table 20: Overview and Description of the 11 FY16 MOD Sandbox Projects

State	Project Sponsor	Description
IL	Chicago Transit Authority	Incorporate the local bike sharing company, Divvy, a 580-station bike share service, into CTA's existing transit trip planning app ($400,000).
TX	Dallas Area Rapid Transit	Integrate ride-sharing services into its GoPass ticketing app to solve first- and last-mile issues ($1,200,000).
CA (WA)	Los Angeles County Metropolitan Transportation Authority	Two-region MOD partnership with the car-sharing company, Lyft, in Los Angeles and Seattle to provide first- and last-mile solutions ($1,350,000).
CA	City of Palo Alto	Proposed solutions seek to reduce Bay Area SOV commute share from 75 percent to 50 percent through a fair value commuting solution ($1,080,000).
WA	Pierce County Public Transportation Benefit Area Corporation	Utilize Limited Access Connections project, an initiative connecting Pierce Transit local service and Sound Transit/Sounder regional service with local ride-share companies to increase regional transit use ($206,000).
AZ	Regional Transportation Authority of Pima County	Adaptive Mobility with Reliability and Efficiency project, integrating fixed route, subscription based ride-sharing and social carpooling services into an existing data platform to provide affordable, convenient and flexible service ($670,000).
FL	Pinellas Suncoast Transit Authority	A set of partnerships with Lyft, United Taxi, CareRide, the Center for Urban Transportation Research, and Goin' Software to develop a model to provide more cost-effective on-demand door-to-door paratransit service ($500,000).
CA	San Francisco Bay Area Rapid Transit	Partnership between Scoop Technologies, Inc., BART, and the Metropolitan Transportation Commission to better integrate carpool access to public transit by matching passengers according to their destination and providing a way to reserve and pay for parking spaces at BART stations ($358,000).
OR	Tri-County Metropolitan Transportation District	Incorporate shared use mobility options into the Open Trip Planner project, that will create a platform integrating transit and shared mobility options ($678,000).
AZ	Valley Metro Rail, Inc.	Smart phone mobility platform that integrates mobile ticketing and multimodal trip planning ($1,000,000).
VT	Vermont Agency of Transportation	Statewide transit trip planner that will enable flex-route, hail-a-ride, and other non-fixed route services to be incorporated into mobility apps ($480,000).

Evaluation of the MOD Sandbox Demonstration Projects

The MOD Sandbox also provides FTA with the opportunity to measure project impacts and assess how existing FTA policies and regulations may support or impede these new service transportation models through evaluation of all project efforts.



Source: USDOT, September 2016

Figure 15: Evaluation of MOD Sandbox Demonstration Projects

The MOD Sandbox is designed to push the boundaries of public transportation by experimenting with the integration of innovative business models and advanced technologies (e.g., smartphone apps, mobile payment, sensing). The goal of these initiatives is to unlock efficiencies and improve mobility through many of the developments that have occurred in recent years, but they have yet to be fully integrated into public transit operations (summarized in Figure 15). There are a variety of examples in which innovative mobility technologies can enhance access to public transit services (e.g., first- and last-mile). At the same time, these services may also compete with public transit. Sometimes this competition can be useful; particularly, if such technologies provide a travel alternative within highly congested corridors.

The innovations developed in the MOD Sandbox have the potential to alter how public transit is delivered nationwide, create cost reductions, eliminate unnecessary emissions/energy use, and increase mobility for citizens in all types of land-use environments.

Relevance to MOD: The MOD Sandbox Demonstration provides a venue through which integrated MOD concepts and solutions (supported through local partnerships) are demonstrated in real-world settings. This Sandbox helps with exploration of types of MOD partnerships, new business models, integration between transit and MOD solutions, and investigating new enabling technical capabilities such as integrated payment systems, decision support, and incentives for traveler choices.

Smart City Challenge

In December 2015, FHWA issued the first Notice of Funding Opportunity for the Smart City Challenge. Seventy-eight cities submitted proposals for the USDOT's Smart City Challenge, and many applicants used MOD services to address a variety of urban mobility challenges and engage a diverse array of stakeholders. For example, Atlanta proposed a network of multimodal transportation centers serving as hubs for mobility, economic development, and community activity. Las Vegas proposed using connected autonomous shuttles to transport workers to Las Vegas Boulevard and new solar powered electric vehicle charging stations would help reduce emissions. Atlanta and Las Vegas are just two of many examples that included advanced traveler information systems and mobility hubs with MOD services. Many Smart City Challenge applicants incorporated advanced transit systems, automated vehicle electric shuttles, and carsharing services into their proposals. (USDOT)

The winner of the Smart City Challenge, Columbus, OH, offered a suite of MOD solutions. Columbus' application focused specifically on increasing social equity and access to opportunity, thus using innovative technology to better connect disadvantaged populations to opportunity.

In its application, Columbus outlined plans for several significant transportation innovations—an autonomous vehicle test fleet that will connect a transit terminal to a job center; increased travel options in poor neighborhoods to better connect expectant mothers to health services; expansion of electric vehicle infrastructure; a multimodal transit pass payment system that will include transit as well as ridesharing and ride-hailing services; and kiosks that can reload transit cards for low-income residents without credit cards or bank accounts.

Relevance to MOD: Many of the solutions in the Smart City Challenge proposals included advanced traveler information systems with MOD solutions, which would enable on-demand requests from kiosks and smartphones. These applications commonly featured transit systems, automated vehicle electric shuttles, and carsharing services. These are elements of MOD that are important to its growth and should be further studied. The insights gained from the Smart City Challenge should be leveraged in any future MOD program research and activities.

Other Agency MOD-Related Programs

MOD is also a component of research outside of the USDOT and within other branches of government and research institutes. For example, the DOE has investigated environmental benefits to on-demand transport. Thus, a variety of potential coordination and program interdependencies between the USDOT and other agencies exists around MOD. This section discusses some of the MOD-related activities and initiatives from the following agencies:

- DOE
- DOD
- DOC
- DOL
- Transportation Research Board (TRB) of the National Academy of Sciences.

DOE and USDOT Collaboration to Support Smart Transportation Systems and Alternative Fuel Technologies

The DOE and DOT are collaborating to accelerate research, development, demonstration, and deployment of innovative smart transportation systems and alternative fuel technologies. The two departments formalized this collaborative relationship through an MOU that was unveiled at the Achieving Zero-Emission Mobility: The Role of Innovative Electric Vehicle Companies symposium, hosted by the University of California Center on Economic Competitiveness in Transportation at Berkeley, California. The MOU will facilitate coordinated actions to leverage the two departments' expertise in transportation energy technology and safety systems to accelerate the analysis, tools, and applications of those technologies.

The joint initiative followed the USDOT's announcement of the Smart City Challenge for demonstrating and deploying vision-forward smart city and mobility solutions. The DOE intended to provide in-kind support of the USDOT's Smart City Challenge in the form of expertise and resources including the DOE's extensive experience in transportation electrification and alternative fuel vehicle fleet deployment through the DOE SMART Mobility consortium, EV Everywhere, and Clean Cities.

The Energy Department's support for Smart City-related activities aligns with the Office of Energy Efficiency and Renewable Energy strategic goal to accelerate the development and adoption of sustainable transportation technology.

Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation (TRANSNET) Project

As part of the DOE's Advanced Research Projects Agency-Energy, TRANSNET seeks solutions that minimize energy consumption in America's surface transportation network through the use of network control mechanisms that operate through personalized signals directed at individual travelers. MOD has been a component for some of the projects funded. A few examples include:

- *Palo Alto Research Center (PARC), Palo Alto, CA*; Collaborative Optimization and Planning for Transportation Energy Reduction: PARC will develop a system that identifies the energy-efficient routes most likely to be adopted by a traveler. PARC's system model will use currently available data from navigation tools, public transit, and ITS to simulate the Los Angeles transportation network and its energy use. PARC's technology will evaluate multiple travelers at the same time, organized by their most likely corridors of travel, to create dynamic ridesharing options.
- *University of Maryland (UMD) at College Park, College Park, MD*; Integrated, Personalized, Real-Time Traveler Information and Incentive Technology for Optimizing Energy Efficiency in Multimodal Transportation Systems: The National Transportation Center at UMD and its partners will develop a technology capable of delivering personalized, real-time traveler information to users and incentivizing travelers to adopt more energy-efficient travel plans. The project team will use data from UMD's existing regional integrated transportation information system as well as other available resources to design its system model. This system model will integrate information on individual traveler behavior to simulate the effects of traffic and traveler choices on energy use in the Washington/Baltimore metro area. For its control architecture, UMD researchers will apply behavioral research to predict travelers' responses and identify appropriate, personalized incentives to encourage drivers to alter routes, departure times, and driving styles, or to take mass transit or shared-ride services.

Applied Robotics for Installation and Base Operations (ARIBO)

Initiated by the U.S. Army, ARIBO is a series of automated vehicle pilots that aims to deploy autonomous vehicle taxi deployments in enclosed environments like army bases, campuses, or dedicated roadways. ARIBO includes automated on-demand, 100-percent electric shuttles and considers remote monitoring capabilities, fleet management, and inductive charging. ARIBO pilots include West Point; Fort Bragg; Fort Leonard Wood; Tampa; Medical City Orlando; Greenville, SC; and others (Clothier). The USDOT collaborates with ARIBO program, and it is a partner of ATTRI.

DOC Study on Digital Matching Firms

DOC published the *Digital Matching Firms: A New Definition in the Sharing Economy* report. This report provides the first-ever government definition of "digital matching firms," which are companies that use Internet and smartphone-enabled apps to match service providers with consumers; help ensure trust and quality assurance via peer-rating services; and rely on flexible service providers who use their own assets, when necessary. The report provides an initial assessment of the sector's size and scope based on publicly available data of the largest firms in the industry. It also examines the potential effect of what is commonly known as the "sharing economy" on consumers and service providers.

The report outlines and elaborates on benefits introduced to the labor force by MOD (Telles, 2016):

- Provides flexible employment schedules and additional income for workers
- Leverages excess capacity and underused assets
- Potentially stimulates new consumption by providing consumers with access to services that were previously either unavailable or less convenient.

The report also outlines and elaborates on challenges introduced to the labor force by MOD:

- Capital investment and maintenance costs are the responsibility of the service provider
- Negative impact on the traditional taxi industry
- Difficulty providing equal access to services for individuals with disabilities.

This study helps with better understanding the underlying economic changes that have played a role in shared mobility, which is a big component of MOD. It also informs the MOD program of the effects of shared mobility in the labor market.

DOL "Future of Work" Series

On December 10, 2016, the DOL hosted a symposium on the future of work. This involved numerous speakers, social media discussion, and papers dedicated to the topic of the changing workforce. Contingent and alternative work arrangements, such as those used by MOD providers (e.g., Uber and Lyft) were a prominent focus topic. The symposium published a series of papers titled the "Future of Work Series," which articulated these work arrangements (Bernhardt, Batt, Houseman, & Appelbaum, 2015). The following summarizes each paper's focus area with relevance to MOD.

"Domestic Outsourcing in the U.S.: A Research Agenda to Assess Trends and Effects on Job Quality:" This paper has specifically pinpointed on-demand ridesharing providers, such as Uber and Lyft, as a candidate for research on the effect of domestic outsourcing within the United States on job quality.

To facilitate research, the paper recommends asking the following three questions:

1. How common is domestic outsourcing, has it grown over time, and how many workers are affected?
2. What are the drivers of domestic outsourcing, in particular industries or production networks, and what are the different forms it takes?
3. What is the effect of domestic outsourcing on job quality and the employment relationship?

The Changing Structure of Work: Implications for Workplace Health and Safety in the U.S.: This paper recommends that the Occupational Safety and Health Association and its sister enforcement agencies place a heavier emphasis on recognizing the specific enforcement challenges (and opportunities) associated with contingent and alternative work arrangements, such as those generally employed by shared mobility providers. The paper reiterates that occupational safety and health (and the control of risks to workers) is a multidimensional and highly contextual challenge—specifically, a challenge where investigating the changes in work relationships through the MOD suppliers' modern-day work models are a piece of the puzzle.

The insight gained from this paper series could be very informative to any MOD-related policy research conducted as part of the MOD program. Key people contributing to the paper series should be included in any stakeholder outreach discussions on MOD-related policies.

Key Takeaways

The key takeaways include:

- There are many ongoing programs within the USDOT that have contributed to the overall vision of MOD and could be leveraged further to make progress toward achieving the full vision of MOD.
- These initiatives have focused on specific aspects including technology, data-centric transportation integration, operations and management, policy and standards, and pilot programs.
- For the MOD program to grow and evolve, it is critical to have close collaboration with key initiatives including the ICM, ATDM, MSAA, MOD Sandbox, and ATTRI programs. Moreover, close collaboration with other agencies including DOE, DOD, DOL, APTA, and Transit Cooperative Research Program will be instrumental to advancing the USDOT's MOD program.

Chapter 10. MOD Research Needs

Mobility (of people and goods) is being disrupted and is experiencing a rapid evolution. A fundamental shift in mobility services has occurred with the rise of on-demand transportation, shared mobility, and the commodification of transportation services. The USDOT MOD program is trying to understand and leverage these innovations to support a traveler-centric, connected, integrated, and multimodal transportation system. MOD embraces all modes and resources to support personal mobility choices for all travelers and goods delivery in an integrated manner. A core component of MOD is the provision of a dynamic supply of mobility services. In addition to planning for a multimodal transportation system, the USDOT has been promoting a fully integrated and dynamic transportation system to enable smarter, more efficient, and safer mobility.

Source: USDOT, August 2017

Figure 16: MOD Research Agenda

This chapter recommends eight core areas that the USDOT should consider to support its research agenda in this area: 1) Economics Impact; 2) Travel Behavior Impacts (e.g., modal shift, auto ownership, energy, environment); 3) Energy and Environmental Impacts; 4) Social Equity and Environmental Justice; 5) Future of Mobility; 6) Policy and Regulations (e.g., land use, equity, finance, labor, tech transfer); 7) Data Management, Sharing, and Standardization; and 8) Transportation Planning. Some of the challenges pursuing these research activities include:

- Limited funding and staffing;

- Risk adverse local agencies or agencies that do not have the funds or institutional support to try new technologies;
- Limited knowledge of potential benefits;
- Finding the right approach and finding private sector partners for getting pilots and research started; and
- The inability of the public and private sectors to reach consensus on data sharing and data privacy for both users and proprietary business information and trade secrets.

Economic Research

MOD is of great economic importance to the nation, cities, and the well-being of households and travelers. At present, there is a need for economic studies that collect data and evaluate the impacts of MOD. For example, to understand the broader impact of passenger and goods delivery services on the U.S. economy, baseline industry metrics on the number of operators, users, fleet sizes, fleet ages, and fleet use are needed, both on an aggregate and regional (e.g., metropolitan statistical area level). Better understanding of the economic impacts and growth of non-traditional employment (e.g., independent contractor drivers) and passive income generation (e.g., P2P carsharing leasing income) is necessary to understand the economic impacts of changes within the transportation sector. The USDOT should consider advancing existing and developing new partnerships with other federal agencies to advance the understanding of the economic impacts of MOD and MOD-related technologies, such as automation and artificial intelligence.

Until recently, MOD research has focused on travel behavior and environmental impacts rather than economic (macro and micro) and labor impacts. The ongoing growth and mainstreaming of MOD and its economic impact is undeniable, yet also not quantifiable given existing methods and research. The USDOT aims to answer many of these and other interdisciplinary economic research questions. Table 21 summarizes key economic research needs.

Table 21: MOD Economic Research Needs

Subject Area	Research Need	Research Question
Industry Benchmarks [USDOT]	1. *Industry Benchmarking* – There is a need to explore the economic impacts of the sharing economy, shared mobility, MOD, and courier services on the transportation network. To understand this question, key industry benchmarks are needed to comprehensively track MOD over time.	What are the key industry benchmarks (e.g., operators, users, packages delivered, fleet sizes, fleet ages) for MOD passenger and goods delivery services nationally and on a state and regional level?

Subject Area	Research Need	Research Question
Gross Domestic Product (GDP) Jobs Wages Workforce Development [USDOT, US DOC, US DOL]	2. *Economic Impacts of MOD* – There is a need to understand the impacts of MOD on key economic indicators (i.e., GDP, jobs, wages) and the broader economy. There is also a need to quantify the economic impacts of service accessibility and economic costs of MOD. For example, do MOD services yield micro and macro-economic growth? Does the lack of MOD services result in slower or foregone economic growth?	a. What is the aggregate impact of MOD on national, state, and regional GDP? b. How much capital generation/GDP growth is generated from P2P transportation services by leasing underused transportation assets? c. How much capital generation/GDP growth is generated from innovative mobility and delivery services? d. How many jobs and wages/GDP growth is generated by MOD employment (e.g., for-hire vehicle drivers, couriers, operations staff, and back-office operations)? e. Is shared mobility creating more wage-earning jobs or is it displacing traditional transportation jobs? Are new jobs sustainable or susceptible to replacement due to the impacts of automation? What types of workforce development programs are needed to retrain and replace transportation workers displaced by automation? What will be the economic impacts of automation and other emerging and future technologies on jobs, wages, and GDP? f. What are the economic impacts associated with enhanced access to jobs, healthcare, and other critical services? g. What are the economic costs for households and communities lacking MOD services?
Capital Projects Infrastructure Maintenance Transportation Finance	3. *Economic Costs of MOD on Public Infrastructure* – There is a need to understand the economic costs of private sector transportation services on the transportation network and potential public policies to ensure that MOD services are paying for their public infrastructure use.	What are the economic costs of MOD passenger and goods delivery services on public infrastructure (e.g., capacity and maintenance)? What types of policies can be implemented to ensure that MOD services pay for their use (new capacity and maintenance) of the transportation network?

Subject Area	Research Need	Research Question
Modal Choice Price Elasticity	4. *Commodification of Transportation* – There is a need to understand the commodification of transportation and how price, travel time, and convenience impact modal and multimodal choices.	a. What are the economic impacts of the commodification of transportation? Does pay-per-trip/pay-per-distance transportation save travelers money (e.g., under what usage and pricing scenarios)? b. From an end-user perspective, when does it make more economic sense to use MOD and when does it make more economic sense to use own a private vehicle (or a private automated vehicle)?
Gross Domestic Product Jobs Wages Workforce Development	5. *Economic Impacts of Reduced Vehicle Ownership* – There is a need to understand the economic impacts of reduced vehicle ownership. At present, insufficient research exists to understand if shared automated vehicles (SAVs) reduce the nation's GDP (due to fewer vehicles produced and owned) or if SAVs increase GDP (due to more intensive vehicle use and higher fleet turnover). More research is needed on a variety of automated vehicle adoption scenarios including a variety of SAV market penetration rates, household vehicle sales, or household vehicle slimming (e.g., a family shares one privately-owned automated vehicle versus maintaining multiple household vehicles).	What are the employment and GDP impacts of reduced vehicle ownership in an automated vehicle future?
Cost Savings Public Administration	6. *Cost Savings for Public Agencies* – At present, public agencies allocate extensive fiscal resources for demand-responsive services. There is a need to understand the role, opportunities, challenges, and potential cost savings of using MOD services to meet some of these service needs.	How can MOD be leveraged to yield cost savings (e.g., more cost effectively providing demand-responsive services or serving users with special needs)?
User and Household Savings User Productivity	7. *Economic Impacts of MOD on Households/Individuals* – In addition to macro-level impacts (e.g., jobs, GDP), there is a need to understand the economic impacts of MOD on a user and household level, such as household cost savings, increased productivity (e.g., ability to work/bill hours while on public transit), etc.	a. What are the economic impacts of MOD on individual users and households? b. What are the impacts of MOD on individual productivity?

Subject Area	Research Need	Research Question
Travel Behavior Capital Projects	8. *Economic Impacts of Changing Consumer Preferences* – There is an increasing shift from brick-and-mortar consumption to online marketplaces. At present, there is virtually no research on the transportation impacts on changing trip generation or VMT impacts from changing consumer preferences. More research is needed to understand the economic impacts and infrastructure needs associated with changing consumer trends.	a. What are the economic impacts of increased goods delivery and reduced passenger trips? b. What infrastructure improvements (e.g., capacity enhancements) are needed to accommodate a growth in goods delivery in the near term and in an automated future)?

Travel Behavior Research

Travel behavior is undergoing a period of notable change in the United States. The nature of how Americans travel is evolving, and this evolution is beginning to reveal itself in long-standing transportation metrics. While the United States has been and is still heavily dependent on the personal automobile for mobility, changes in technology, demographics, economics, and attitudes are transforming how mobility is attained. At the same time, advances in information technology are opening new ways for transportation activity to be measured more comprehensively.

The sharing economy has grown alongside emerging ICT systems, which facilitate the sharing of assets that would have otherwise been used by one individual or household. MOD represents an innovative transportation solution that enables users to have short-term access to a shared passenger mode or goods delivery on an as-needed basis. MOD is evolving to meet the needs of cities and consumers whose attitudes have begun to shift toward on-demand mobility and consumer goods access.

More research is needed on the concepts of commodification, pricing, price elasticity, and MaaS. Historically, America has been culturally oriented toward ownership-based “all you can use” consumption (e.g., flat-rate pricing, unlimited data, all you can eat buffets, free refills, Netflix, Amazon Prime deliveries). More research is needed to understand cultural differences that could impact privately owned- and shared-automated vehicle adoption, the role of incentives, and pricing models.

MOD has the potential to significantly impact travel behavior (both positive and negative). Far more travel behavior research is needed to more fully understand the varying impacts of MOD services, variations by built environment/local context, the role of commodification, and the growth of goods delivery. For example, some consumers may use technology to consolidate trips (e.g., multimodal trip planning), and others may use it to increase trips (e.g., increased goods delivery).

More pilots, data, and research are needed to understand the travel behavior and environmental impacts of existing and emerging MOD services. The USDOT aims to answer many of these and other interdisciplinary travel behavior research questions. Table 22 summarizes key travel behavior research needs.

Table 22: MOD Travel Behavior Research Needs

Subject Area	Research Need	Research Question
Best Practices Regional Comparisons	1. *MOD vs. MaaS* – There is a need to understand similarities and differences between MOD/MaaS in the European and U.S. contexts to better understand lessons learned and best practices for North American application.	a. What are the MaaS models in Europe and will they work in the U.S.? b. What similarities, differences, best practices, and lessons learned are applicable to the U.S.?

Subject Area	Research Need	Research Question
Impact Studies Impacts on Public Transportation Impacts Comparison	2. *Impact Studies* – There is a need to enhance understanding of MOD impacts for existing and emerging service models. Unstudied modes and various results from studied modes have raised questions about the impacts of MOD (e.g., modal split, VMT, public transit, auto ownership), regional and site-specific variations, and how to plan for MOD when the impacts vary considerably.	a. What are the impacts of existing and emerging MOD modes (e.g., microtransit)? b. What are the impacts of MOD on vehicle ownership, VMT, emissions, equity, and accessibility (e.g., jobs, health care, healthy food, etc.)? c. What are the impacts of MOD on public transportation? Does MOD complement or compete with public transportation and under what circumstances/contexts?
Impacts Studies Impacts Comparison	3. *Impacts of Commodification* – There is very little research on the impacts of commodifying the transportation network. There is a need to enhance understanding of travel impacts, opportunities, and challenges for both users and operators.	What are the travel behavior impacts of transportation commodification? Does it work well for users? Does it work well for operators?
Regional Variations Impact Modeling Future Forecasts	4. *Local and Regional Impacts* – In many cases, MOD impacts have not been studied and compared across regions using the same methodology. In a few cases where cross-regional studies have been conducted, the impacts of MOD tend to vary (in some cases quite considerably). There is a need to understand how site- and region-specific characteristics impact MOD modes and travel behavior.	a. What are the impacts of MOD on a local and regional level? How do these impacts vary based on the built environment, urban form, and other localized characteristics? b. Can predictive modeling be developed to forecast the impacts of MOD based on local and regional characteristics and by time of day?
Incidental Trips Pooling Incentives	5. *Incidental Trips (Carpooling/Vanpooling)* – There is a need to understand how MOD can be leveraged to support incidental trips (e.g., existing travelers and roadway users spontaneously pair rides thereby increasing occupancy and reducing demand).	a. How can MOD support carpooling/vanpooling trips? b. What types of policies and incentives are needed to get people who are already traveling to pick up someone in their vehicle?

Subject Area	Research Need	Research Question
Goods Movement Future Trends	6. *MOD Goods Movement* – There is very little existing literature on the impacts of urban goods movement and online deliveries on the transportation network. There is a need to understand how the growth of online commerce will impact trip generation, VMT, and infrastructure planning.	a. What are the impacts of increased urban goods delivery on the transportation system, overall? b. Does an increase in goods delivery yield VMT reductions and environmental benefits (through fewer passenger trips) or does it increase VMT and emissions through more delivery trips?
Macro Productivity Micro Productivity	7. *Productivity* – There is a need to understand the impacts of MOD on macro (transportation system) and micro (personal) productivity.	What are the impacts of MOD on transportation network productivity (macro) and personal/household (micro) productivity?
Travel Behavior Modal Choice Price Elasticity	8. *Impact of Cultural Norms on Pricing and Modal Choice* – There is a need to understand how cultural norms of ownership and unlimited consumption will impact the adoption of MOD and/or MaaS in the North American context.	a. How will cultural notions of ownership, flat-rate pricing, and unlimited consumption impact the adoption of MOD in the American context? Can per-trip or per-distance pricing become mainstream in the U.S. or should other pricing models be considered (e.g., a monthly mobility pass)? b. What are the price and time elasticities of consumers in response to MOD services and the decision forgo a vehicle purchase or sell a private vehicle?
Feebates Travel Behavior Public Policy	9. *Feebates* – Feebates is a system of charges and rebates (i.e., incentives) whereby energy-efficient or environmentally friendly practices are rewarded (e.g., alleviating congestion), while failure to adhere to such practices is penalized (e.g., adding to congestion). There is a research need to understand how feebates could be employed as part of the MOD ecosystem.	a. How could feebates be used to incentivize higher occupancy trips or trips at lower demand times of day? b. What are the economic and equity impacts of a feebate policy applied to MOD?

Energy and Environmental Impacts

An increasing body of empirical evidence indicates that MOD modes have numerous environmental and energy impacts. While impact studies on carsharing and public bikesharing are fairly extensive, the impacts of newer service models and emerging modes, such as scooter sharing, on-demand ride services (such as ridesharing and ridesourcing), and courier services are less studied and understood. There is additional uncertainty associated with automated vehicle impacts on energy and the environment making these new technologies challenging to model and understand. Additionally, shared automated vehicles could result in notable growth beyond cities into suburban and rural locations. More research is needed - particularly on the city and regional level and across the growing ecosystem of MOD services. Table 23 summarizes key MOD energy and environmental impacts research needs.

Table 23: MOD Energy and Environmental Impacts Research Needs

Subject Area	Research Need	Research Question
Impacts Studies Impacts Comparison	1. *Impact Studies* – There is a need to enhance understanding of MOD impacts for existing and emerging service models. Unstudied modes and various results from studied modes have raised questions about the impacts of MOD, regional and site-specific variations, and how to plan for MOD when the impacts vary considerably.	a. What are the energy and environmental impacts of existing and emerging MOD modes? b. What are the impacts on energy consumption, criteria pollutant emissions, and GHG emissions (e.g., feebates)?
Impact Modeling Future Forecasts	2. *Connected and Automated Vehicles* – There is a need to understand the impacts of MOD in a connected and automated vehicle future. More research is needed on the impacts of connected and automated vehicles on service models, user experience, and energy/environmental impacts.	a. What are the impacts of connected and automated vehicles in a MOD future (e.g., energy consumption, GHG, etc.)? b. How do these impacts vary by region/built environment and temporal scale?

Social Equity and Environmental Justice

While the user base of MOD is growing, it still represents a small fraction of the U.S. population and total trips. As of May 2016, only 15 percent of Americans had used ridesourcing apps, and 30 percent had never heard of them (Smith, 2016). While the number of carsharing and bikesharing markets and membership numbers continue to grow, they are still mostly confined to dense urban areas and represent a small percentage of regional travel. Despite potentially providing disadvantaged communities with additional service offerings, MOD has failed to gain traction among these groups, with MOD surveys showing user bases that underrepresent low-income and non-white users. The lower rates of MOD usage among the poor have many plausible explanations including lack of availability in low-income neighborhoods and limited Internet, lack of smartphone, credit/debit card access, and cost of services are. There is also a need to provide access to those less familiar with smartphones technology (e.g., older adults), as well as people with disabilities. Some of these populations could benefit a great deal from on-demand mobility. Most experts agreed that more robust nationwide research was needed to fill gaps in knowledge about users and non-users, and existing policy barriers to piloting and implementing equitable MOD services. Table 24 summarizes key social equity and environmental justice research needs.

Table 24: MOD Social Equity and Environmental Justice Research Needs

Subject Area	Research Need	Research Question
Serving People with Disabilities Equivalent Service Public Policy	1. *Serving People with Disabilities* – There is a need to understand how MOD can be used to enhance access and mobility for people with disabilities.	a. How can MOD provide ambulatory and non-ambulatory access and mobility to people with disabilities? b. How will payment be handled for services among providers, including subsidies? c. What types of equipment standards and worker training are necessary to provide people with disabilities the best possible MOD service? d. Do MOD services provide equivalent service? If equivalent service is not provided, what types of policies or programs can be implemented to ensure equivalent level of service (e.g., system-wide user fees to pay for paratransit service)? e. What type transformative solutions, applications, and systems can be employed to expand MOD to people with disabilities and ensure equivalent service (e.g., skilled training for ridesourcing/TNC drivers to provided door-to-door assistance)?

Subject Area	Research Need	Research Question
Fare Payment Technologies Public Policy	2. *Serving Unbanked and Underbanked Users* – The Federal Deposit Insurance Corporation (FDIC) estimates that there are 10 million unbanked or underbanked American households (many of whom may be low-income). More research is needed into programs and technologies that allow MOD and public transit to serve these users (e.g., pairing transportation payment/subsidies with housing programs).	How can payment and banking challenges (e.g., under- and un-banked users) be overcome in an increasingly digital world?
Service Access Technologies Public Policy	3. *Digital Divide* - Since many MOD services require mobile data and apps for service use, there is a need to understand how the lack of mobile Internet access can impact service accessibility and the policies that can help preserve user access to MOD.	a. How many users are unable to access MOD because of the lack of mobile Internet access or understanding of how to use these services (e.g., older adults, rural residents, low income)? b. What alternative methods and/or policies can be implemented to allow service accessibility in an increasingly digital world?
Special Populations	4. *Serving Other Special Populations* - There is a need to understand how MOD can be used to enhance access and mobility for special populations (e.g., children, prenatal mothers, veterans, etc.).	a. How can MOD enhance access and mobility for a variety of special populations and demographic segments (e.g., children, prenatal mothers, veterans, etc.)
Impacts on Public Transportation Public Policy	5. *Impacts of MOD on Public Transportation* – In many cases, public transportation provides accessibility for underserved communities. More research is needed on the impacts of MOD on public transportation and vulnerable populations.	a. Does MOD complement or compete with public transportation? b. If MOD competes with public transportation, what types of policies, regulations, or other measures are needed to ensure access to vulnerable populations?
User Demographics	6. *User Demographics* – There is a need to develop survey questions and incorporate MOD into national travel surveys (e.g., low-income, rural, suburban, urban).	a. Who uses MOD and who does not use MOD? b. What are the MOD and non-MOD modal choices of Americans on a census block, tract, regional, state, and national level?

Subject Area	Research Need	Research Question
Policy Barriers Equivalent Level of Service	7. *Policy Barriers* – There is a need to asses existing policies (local, state, and federal) for their unintended impacts on MOD equity, access, and equivalent level of service.	a. What policies support equitable access to MOD services? What policies are inhibiting equitable access to MOD services? b. Does MOD provide equivalent level of service (and under what contexts)? If not, what types of policy (or other) reforms need to be implemented to ensure equivalent level of service for all protected classes?

Future of Mobility Research

MOD is evolving, alongside many technological advances. Understanding how current and future technology is impacting MOD and how it could be leveraged to address the challenges of our transportation system is important.

Automated and connected vehicles have the potential to improve safety, maximize infrastructure capacity use, enhance traveler convenience, and potentially lower transportation costs. There is an opportunity to complement existing transportation infrastructure with technology solutions to boost network capacity where expansion of transportation assets would be costly or prohibitive due to physical/financial constraints. However, these advances are not without risk, and technological innovation must be protected by physical and digital security. Automated systems could be used to deliver biological, nuclear, explosive, and other weapons. The hacking of the transportation networks could also cripple our nation's security and the economy. The USDOT should consider developing a joint program with the U.S. Department of Homeland Security's Science and Technology Directorate to develop a future roadmap for transportation cyber security and safety.

Drones have the potential to enhance urban goods movement and offer direct B2C deliveries at a reduced cost. The growth of drones in urban goods movement could have far-reaching impacts on the transportation network, such as safety risks for aviation and reducing VMT. As such, intra-agency collaboration may be needed to address drone operations (e.g., airspace considerations, permissive use, operation standards, regulation, landing locations). The USDOT should consider a joint MOD research program and sandbox to test passenger and goods delivery aviation concepts and innovations including passenger AAVs and drones for goods delivery. This research program and Sandbox should include a variety of study areas including potential airspace rules and classifications needed to accommodate aerial MOD innovations, safety, take-off and landing procedures, and security.

Finally, USDOT should consider conducting a national "Smart Infrastructure Capability Assessment" in conjunction with other federal partners and the private sector to identify major technological assets available to the USDOT and other federal agencies to leverage ICT and data to more intelligently manage the transportation network and identify possible gaps for automated MOD services. This will provide a baseline of quantitative data, which could serve as a foundation for the development of a national ICT strategy to build the fiber optics and other digital infrastructure needed to advance America's transportation network into the 21st Century and beyond into fully automated systems. This assessment could focus on identifying asset value, historical and forecast investment, ICT infrastructure performance, and current and future ICT capacity necessary for the USDOT.

Table 25 summarizes key future of mobility research needs.

Table 25: MOD Future of Mobility Research Needs

Subject Area	Research Need	Research Question(s)
Foundational Research	1. *Future of Mobility* – There is a need for foundational research at the federal level on future mobility technologies, particularly around AAVs, artificial intelligence, drones, and robotic delivery, including their impacts on the transportation system and needed infrastructure and public policy.	a. What are the potential opportunities and challenges introduced by the emerging technologies on the transport system, infrastructure, and policy?
Scenario and transportation modelling Scenario Analysis	2. *CVs/AVs, Occupancy, Vehicle Miles Traveled, and Future Scenarios* – There is a need to understand the potential impacts of CVs and AVs on average vehicle occupancy and VMT, both in a privately owned and shared setting.	a. What are the possible MOD future scenarios that reflect key technological innovations, such as AVs, AAVs, drones, and robotic delivery? b. What are the impacts of CVs/AVs on congestion and VMT?
ICT Infrastructure Assessment	3. *ICT Assessment* – There is a need to inventory existing ICT assets, gaps, and future ICT infrastructure needs to respond to changes in the transportation network.	a. What are major technological assets available to the USDOT and other federal agencies to leverage ICT and data to more intelligently manage the transportation network? b. What are future opportunities and challenges associated with USDOT's infrastructure capabilities, specifically related to how existing ICT infrastructure can be used to accommodate future demand?
Foundational Research MOD and ICM	4. *MOD and ITS* – There is a need to conduct foundational research on how MOD can integrate with existing corridor operations (e.g., ICM, BRT).	a. What foundational research is needed on existing ITS technologies or operational concepts, such as ICM or BRT operations relating to MOD to help expedite the program from concept to deployment?

Subject Area	Research Need	Research Question(s)
Timed Transfers	5. *MOD and Timed Transfers* – There is a need to understand if/how MOD can be adapted to facilitate timed transfers to minimize traveler inconvenience due to mechanical, congestion, capacity, or other delays.	a. What opportunities exist for facilitating timed transfers between MOD service providers, as well as between MOD service providers and public transportation? b. What types of data, systems, and technologies are needed to advance timed transfers, reduce layovers, and enhance customer experience?
Aerial Vehicles Drones	6. *Joint FHWA-Federal Aviation Administration (FAA) Research Program* – There is a need to develop a joint FHWA-FAA program to research advancements in short-range low-level aerial MOD services, such as AAVs and drones.	Specific research topics could include the impacts of these services, rights-of-way rules, airspace reforms, and safety certifications (for both ground and air-worthiness).
Artificial Intelligence and Machine Learning	9. *Artificial Intelligence and Machine Learning* – There is a need to understand the potential opportunities, challenges, and impacts of artificial intelligence and machine learning on MOD and society.	a. What will be the impacts of artificial intelligence and machine learning on MOD? b. How will user privacy be protected? What unintended consequences may arise from the use of artificial intelligence?

Policy and Regulations Research

To date, little research has been conducted on the types of policies and governmental reforms needed to foster MOD innovations. More research is needed to understand ways that policymakers and regulations can enable more intelligent and efficient use of resources to achieve taxpayer savings and improve service delivery in support of innovation and government efficiency. More research is needed to understand the potential opportunities and challenges of these emerging technologies and guide federal policy development.

Table 26 summarizes key policy and regulations research needs.

Table 26: Policy and Regulations Research Needs

Subject Area	Research Need	Research Question
Foundational Research Built Environment	1. *MOD and Built Environment* – There is a need for foundational research on how public policy can support a variety of MOD use cases in different built environments and urban areas.	a. What policies and incentive structures could be developed to improve MOD in suburban, rural, and urban areas and ensure MOD benefits are realized in different geographic environments?
Equity and Environmental Justice	2. *Social Equity and Environmental Justice* – There is a need to understand how social equity and environmental justice issues relating to MOD can be addressed, overcome, and mitigated.	a. How can MOD improve access to jobs, healthcare, and education for all members of the economy? b. Should there be subsidies for low-income users to ensure equal opportunity and access to jobs, healthcare, and other critical services? If so, how should this program be setup and what safe guards should be implemented to prevent abuse? c. What types of policies need to be in place to ensure equivalent level of service for vulnerable populations and users with special needs (e.g., low-income communities, minority neighborhoods, people with disabilities, etc.)?
Innovation	3. *Fostering Innovation* – There is a need to understand the types of policies and governmental reforms that the USDOT (and other departments) can implement to foster innovation in MOD and the broader the transportation sector.	a. What are the types of policies and governmental reforms needed to foster innovation (e.g., use of drones for urban goods movement, autonomous vehicles and MOD, etc.)? b. What are the relevant public sector and federal requirements, regulations and policies that may

Subject Area	Research Need	Research Question
		support or impede public transit sector adoption of MOD? c. What institutional, regulation, and policy issues at the Federal, State, and local level could hinder future deployment of MOD? d. Are there initiatives that could support MOD development?
Infrastructure Needs Assessment Transportation Finance	4. *Physical Infrastructure Needs* – There is a need to understand what types of capital infrastructure improvements (or changes) may be needed to accommodate MOD and other emerging technologies. It is recommended that the USDOT conduct an infrastructure needs assessment to understand mid- and long-term infrastructure needs to respond to changes in transportation technologies.	a. What type of infrastructure is needed to accommodate MOD and related emerging technologies? b. What funding sources (or financing mechanisms) are available to meet MOD infrastructure needs?
Labor Policy Consumer and Labor Protection Safety Insurance	5. *Multi-Disciplinary MOD Policy Research* – There is a need to develop a multi-disciplinary research program that addresses a wide-array of MOD-related public policy issues, such as labor, insurance, subsidies, equivalent level of service, and others?	a. What types of policies may be needed to protect independent contractor labor in the workforce (e.g., equal opportunity, protection from harassment)? b. What types of policies may be needed to protect MOD labor from dangerous or abusive customers? c. Does the USDOT need to implement maximum weekly and consecutive MOD driving hours (similar to truck driver safety regulations)? If so, what types of policies and technologies are needed to enforce this across multiple app/service providers? d. What types of policies and insurance requirements are needed to protect labor, users, and non-users from crashes, malfunctions, and "acts of god"?
Knowledge Transfer Education and Outreach	6. *Knowledge Transfer* – There is a need to support and augment existing (and future) research efforts with knowledge transfer, education, and	a. What are the benefits, costs, and lessons learned from deployed projects for knowledge sharing and technical transfer (e.g., accelerating adoption among local agencies)?

Subject Area	Research Need	Research Question
	outreach to practitioners, consumers, and policymakers.	
Transportation Finance Public Transportation Finance Subsidies	7. *Transportation Finance* – There is a need to understand how pricing can be employed in the future to guide outcomes and redistribute funds to pay for infrastructure, public transportation, and subsidize low-income riders.	a. What policy options are available to leverage MOD to pay for public infrastructure? b. What policy options are available to leverage MOD to pay for public transportation? c. Should MOD subsidize low-income riders? If so, what policy options are available for subsidies?
Cyber Security Counter-terrorism Consumer Privacy	8. *Joint USDOT-DHS Research Program* – There is a need to develop a joint program with the US Department of Homeland Security (DHS) Science and Technology Directorate identify physical and cyber security vulnerabilities associated with MOD services, both today and in a future automated system.	a. What types of technologies and security protocols need to be in place to protect MOD systems from terrorism or cyber-attacks (e.g., protecting microtransit and SAVs from explosives, cyber-jacking, or hacking)? b. Should user identities be tracked, akin to airline passengers, to deter and respond to system attacks? c. What types of constitutional and privacy related issues does this raise and how can security and privacy both be protected?
Protecting Minors	9. *Joint USDOT-DOJ Research Program* – There is a need to develop a joint program with the US DOJ to identify policies and technologies necessary to protect minors using MOD and automated transportation systems (e.g., abduction, runaway children, etc.).	

Data Management, Sharing, and Standardization

Data management, sharing, and standards are critical to the growth and success of MOD. Generally, MOD services collect a lot of private information from their users. This can include particularly sensitive information, such as addresses, current location, location history, and financial information (for fare payment). More broadly, transportation apps can trace mobility habits and share a user's location (via third-party APIs). Some users may or may not pay attention to the information usage permissions they grant (via user agreements and app installation processes). Often the data and how the data will be shared or used is opaque and confusing to the user. In particular, there is a need to establish a national clearinghouse of MOD resource materials and data by USDOT.

The public and private sectors can aid mobility consumers in making informed decisions about the data they share by ensuring that user agreements are drafted in plain language, comprehensible, and easy to read on mobile devices so that users clearly understand how their personal data may be employed. Standardization is another key research need. Standards are necessary to enable integration and support the development and adoption of MOD information standards. Standards for payment, scheduling, storage of customer information, and privacy considerations are necessary.

Table 27 summarizes the key data management, sharing, and standardization research needs.

Table 27: Data Management, Sharing, and Standardization Research Needs

Subject Area	Research Need	Research Initiative(s)/Question(s)
Foundational Research Data Repositories Protection of Proprietary and Consumer Information ITS Standards	1. *Data Standards and Management* – There is a need for foundational research to establish MOD sector-wide data standards, data repositories, and requirements for participation.	a. Need for national clearinghouse of resource materials by USDOT on MOD (e.g., best practices, definitions, policies, lessons learned, etc.). b. The development of national, state, and regional data exchanges to serve as a repository for public and private sector data sets. c. The establishment of national level data standards including requirements for data sharing and establishing the format(s) and standards for publishing data sets. The USDOT should consider a policy requiring transportation service providers and apps share data with the USDOT as a condition for offering services. • General Transit Feed Specification (GTFS) and GTFS Real-time (GTFS-RT) define a common format for public transit schedules and geographic information reporting. What type of data specifications are needed for MOD and real-time data reporting? d. Establish data management procedures that protect consumer privacy and proprietary data. • How should data metrics be changed and adopted to reflect a multimodal, traveler-centric approach? e. Consider establishing a statutory exemption for sensitive and proprietary transportation data under 5 U.S.C. 552 and USDOT regulations that protect consumer and proprietary business information from release under the Freedom of Information Act and state level public records acts. f. What types of data are available to support MOD research and deployment? Who has the rights to those data and how can USDOT and public agencies get access to it? What services could be changed, if agencies had this information? g. What are innovative service models that may be adopted with regular integration of big data?

Subject Area	Research Need	Research Initiative(s)/Question(s)
Foundational Research ITS Standards	2. *Incorporating MOD into ARC-IT* – There is a need to understand how MOD can be incorporated into the Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) to provide a common framework for planning, defining, and integrating MOD into other ITS programs.	a. What are the connection points between MOD and ARC-IT efforts? How do we incorporate connected MOD travelers into ARC-IT technologies? b. What are the incentives (or needed incentives) and approaches for MOD operators and vendors to follow standards developed by the ITS industry?

Transportation Planning

Urban planners and policymakers should be aware of the potential positive and negative impacts of MOD on local communities. Understanding the impacts of MOD will enable planners and policymakers to leverage positive transportation impacts and environmental outcomes, as well as tame unintended or negative impacts (Cohen & Shaheen, 2016). More research is needed to support effective integration of MOD during the transportation planning phase. While methodologies and datasets have evolved to better understand travel behavior in the 21st century, gaps in understanding remain. One existing gap noted in the literature relates to understanding the impact of travel behavior on local land-use development. A Caltrans study (Houston & Boarnet, 2013) noted that travel behavior studies often are based on average effects on a regional scale, leaving a knowledge gap regarding how to apply this information to local land-use development. For example, California, Senate Bill (SB) 375 requires MPOs to consider land use and transportation planning to reduce greenhouse gases. However, limited knowledge exists on how to apply the impacts of MOD into state transportation planning models. Several new methodologies have emerged in the past 5 years that heavily leverage the advances in smartphone and GPS technologies; however, these new methods have yet to be applied to MOD. New estimation procedures (e.g., activity-based modeling) have also emerged; these are statistically sound and may perform much more efficient forecasting than traditional choice-based estimation models. Table 28 describes some of the key MOD transportation planning research needs.

Table 28: MOD Transportation Planning Research Needs

Subject Area	Research Need	Research Question
Built Environment	1. *Understanding the Role of the Built Environment* – There is a need to understand how various MOD services can be applied across a spectrum of land-use, density, and built environments.	a. How does MOD vary across built environments in terms of business model and services offered? How can this fill gaps in public transit, for instance? b. What types of opportunities exist for MOD in lower density (e.g., suburban, exurban, and rural) locations?
Modeling	2. *Transportation Modeling and MOD* – There is a need to incorporate MOD into transportation modeling and scenario analysis for MPOs with a variety of model types, methods, and levels of sophistication.	a. How can MOD be incorporated in transportation planning tools and models regardless of model sophistication (e.g., sketch planning, 4-step models, activity-based models)? b. How can modeling and scenario analysis be used to improve public transit efficiency and return on investment (e.g., replacing inefficient bus services in suburban areas)? c. How can modeling be used to develop and augment research scenarios that forecast the future of

Subject Area	Research Need	Research Question
		MOD (e.g., with and without automation)?

Concluding Thoughts

As innovative mobility and goods delivery services continue to grow and evolve, the USDOT has the opportunity to guide public policy, support public-private partnerships, and ensure accessibility for all travelers. Additional research and public policy guidance are key to understanding the transformative impacts that MOD is having on the transportation system. These research needs provide the next steps for the USDOT to foster MOD transportation innovation into the 21st century.

Appendix A. Glossary

Active Transportation and Demand Management (ATDM): ATDM is a dynamic approach to manage a system that is both active and predictive. The goal is to identify problems ahead of time and use an approach to manage demand and supply to meet the desired network performance. The primary hypothesis of ATDM is that proactive management yields better results than reactive management and will improve a system's reliability, safety, and environment.

Bikesharing: Users access bicycles on an as-needed basis for one-way (point-to-point) or roundtrip use. Station-based bikesharing kiosks are typically unattended, concentrated in urban settings, and offer one-way station-based access (bicycles can be returned to any kiosk). Free-floating bikesharing offers users the ability to check-out a bicycle and return it to any location within a predefined geographic region. Bikesharing provides a variety of pickup and drop-off locations. The majority of bikesharing operators cover the costs of bicycle maintenance, storage, and parking. Generally, trips of less than 30 minutes are included within the membership fees. Users join the bikesharing organization on an annual, monthly, daily, or per-trip basis.

Carpooling: A formal or informal arrangement where commuters share a vehicle for trips from either a common origin, destination, or both, reducing the number of vehicles on the road.

Car Rental: A non-membership-based service or company that rents cars or light trucks typically by the day or week. Traditional rental car services include storefronts requiring an in-person transaction with a rental car attendant. However, rental cars may also employ "virtual storefronts," allowing unattended vehicle access similar to carsharing.

Carsharing: A program where individuals have temporary access to a vehicle without the costs and responsibilities of ownership. Individuals typically access vehicles by joining an organization that maintains a fleet of cars and light trucks deployed in lots located within neighborhoods, public transit stations, employment centers, and colleges/universities. Typically, the carsharing operator provides insurance, gasoline, parking, and maintenance. Generally, participants pay a fee each time they use a vehicle.

Connected Travelers: are an important piece of the MOD evolution and include both people and vehicles that exchange data among themselves and other parts of the transportation infrastructure.

Courier Network Services (CNS): CNS provide for-hire delivery services for monetary compensation using an online application or platform (such as a website or smartphone app) to connect delivery drivers using a personal transportation mode with a package/item or food delivery requests. These services can also be used to pair package delivery with passenger trips, where for hire-drivers can deliver both passengers and packages, either together or in separate trips.

Demand Response Service: any non-fixed route system of transporting individuals that requires advanced scheduling by the customer, including services provided by public entities, nonprofits, and private providers.

Digital Matching Firms: entities that provide online platforms (or marketplaces) that enable the matching of service providers with customers.

Microtransit: A privately owned and operated shared transportation system that can offer fixed routes and schedules, as well as flexible routes and on-demand scheduling. The vehicles generally include vans and buses.

Mobility as a Service (MaaS): MaaS emphasizes mobility aggregation, smartphone and app-based subscription access, and multimodal integration (infrastructure, information, and fare integration). MaaS tends to emphasize the integration and convergence of passenger mobility services, mobile devices, real-time information, and payment mechanisms.

Mobility on Demand (MOD): an innovative transportation concept where consumers can access mobility, goods, and services on demand by dispatching or using shared mobility, courier services, UAVs, and public transportation solutions. Passenger modes facilitated through MOD providers can include shared modes, public transportation, and other emerging transportation solutions (e.g., aerial taxis). Goods delivery facility through MOD can include app-based and aerial delivery services (e.g., drones).

Peer-to-Peer (P2P) Marketplace: P2P marketplace enables direct exchanges between individuals via the Internet. Terms are generally decided among parties of a transaction and disputes are subject to private resolution.

Public Transportation: Any mass transportation vehicle that charges set fares, operates on fixed routes, and is available to the public. Common public transportation systems include buses, subways, ferries, light and heavy rail, and high speed rail.

Transportation Network Company (TNC)/Ridesourcing: Ridesourcing services (also known as transportation network companies (TNCs) or ride-hailing) provide prearranged and on-demand transportation services for compensation, which connect drivers of personal vehicles with passengers. Smartphone mobile applications are used for booking, ratings (for both drivers and passengers), and electronic payment. There are a variety of vehicle types that can be offered by these services including: sedans, sports utility vehicles, vehicles with car seats, wheelchair accessible vehicles, and vehicles where the driver can assist older or disabled passengers.

Ride-Hailing: Another term for ridesourcing services, as defined above.

Scooter Sharing: Users gain the benefits of a private scooter without the costs and responsibilities of ownership. Individuals typically access scooters by joining an organization that maintains a fleet of scooters at various locations. Typically, the scooter operator provides gasoline, parking, and maintenance. Generally, participants pay a fee each time they use a scooter. They can be roundtrip, one-way, or both.

Shared mobility: an innovative transportation strategy that enables users to have short-term access to a transportation mode (e.g., vehicle, bicycle, or other low-speed travel mode) on an as-needed basis. Shared mobility includes various service models and transportation modes that meet the diverse needs of travelers. Shared mobility can include roundtrip services (vehicle, bicycle, or other low-speed mode is returned to its origin); one-way station-based services (vehicle, bicycle, or low-speed mode is returned to a different designated station location); and one-way free-floating services (vehicle, bicycle, or low-speed mode can be returned anywhere within a geographic area).

Trip Chain: The trip chain represents a series of decisions that affect transportation demand and utilization of the network. There are five key stages within the trip chain that are: destination choice, time of the day choice, mode choice, route choice, and lane/facility use choice.

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