Title

Energy Efficiency - Innovations: Driving Prosperity, Slashing Emissions

ISBN

978-981-121-785-2

Authors

Susan, Shaheen

Adam, Cohen

Publication Date

2020

Chapter 4: Next Generation Mobility Systems

Energy Efficiency – Innovations:

Driving Prosperity, Slashing

Emissions

2020

Susan Shaheen

Adam Cohen

https://doi.org/10.1142/9789811217869_0004

Chapter 4

Next Generation Mobility Systems

Susan Shaheen[*,‡] and Adam Cohen[†,§]
[*]*Department of Civil and Environmental Engineering at the University of California, Berkeley*
[†]*Transportation Sustainability Research Center University of California, Berkeley, California 94720, USA*
[‡]*sshaheen@berkeley.edu*
[§]*apcohen@berkeley.edu*

1. Introduction

In recent years, mobility on demand (MOD) is gaining popularity among mobility consumers. This innovative concept is 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 enables consumers to access mobility, goods and services on demand by dispatching or using shared mobility, delivery services and public transportation solutions through an integrated and connected multi-modal network. This chapter describes the different services that have emerged in the MOD ecosystem and the core enablers of MOD, such as stakeholders, business models and technology. The chapter concludes with a discussion of how MOD and vehicle automation could impact cities and the transportation network and their energy use.

In recent years, technological, economic, and environmental forces are changing the way people travel and consume resources.[1,2] On-demand mobility and delivery services have become part of a sociodemographic trend that has pushed MOD from the fringe toward the mainstream.[3] MOD is changing how people travel and access goods, and it is having a transformative effect on cities.[4] This concept has also been referred to as mobility as a service (MaaS). This chapter has eight key sections. The first two sections define MOD and discuss the similarities and differences between MOD and MaaS. Section 2 reviews the MOD ecosystem including the role of supply and demand and MOD stakeholders. In Section 3, a taxonomy of shared mobility and goods delivery is reviewed. In Section 5, business models and technology enablers are discussed. Section 5 concludes a discussion of how MOD and vehicle automation could impact cities and the transportation network. Section 6 summarizes key findings of this chapter.

2. The Mobility on Demand Ecosystem

MOD is an innovative 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.[3,5] MOD enables consumers to access mobility, goods and services on demand by dispatching or using shared mobility, delivery services and public transportation solutions through an integrated and connected multi-modal network.[3] 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 services include: bikesharing, carsharing, ridesharing (carpooling and vanpooling), transportation network companies (TNCs) (also known as ridesourcing and ridehailing), scooter sharing (including standing electric and moped-styles), microtransit, shuttle services, public transportation and other emerging transportation solutions. The most advanced forms of MOD incorporate robotic delivery, app-based courier network services (CNS), and aerial passenger and delivery services (e.g., urban air mobility and delivery drones). Fundamentally, MOD is about how people make mobility decisions, how they move, how they consume goods and services, and the stakeholders that make it possible.[3]

Commodification is the transformation of transportation services into tradeable commodities or an economic resource.[3,6] As part of this transformation, transportation services are assigned an economic value that can be traded or exchanged in the transportation marketplace for other transportation mode(s) or money.[5,7] MOD emphasizes enhancing mobility options for all users through the integration of on-demand modal services, public transportation, payment mechanisms, traveler incentives and an

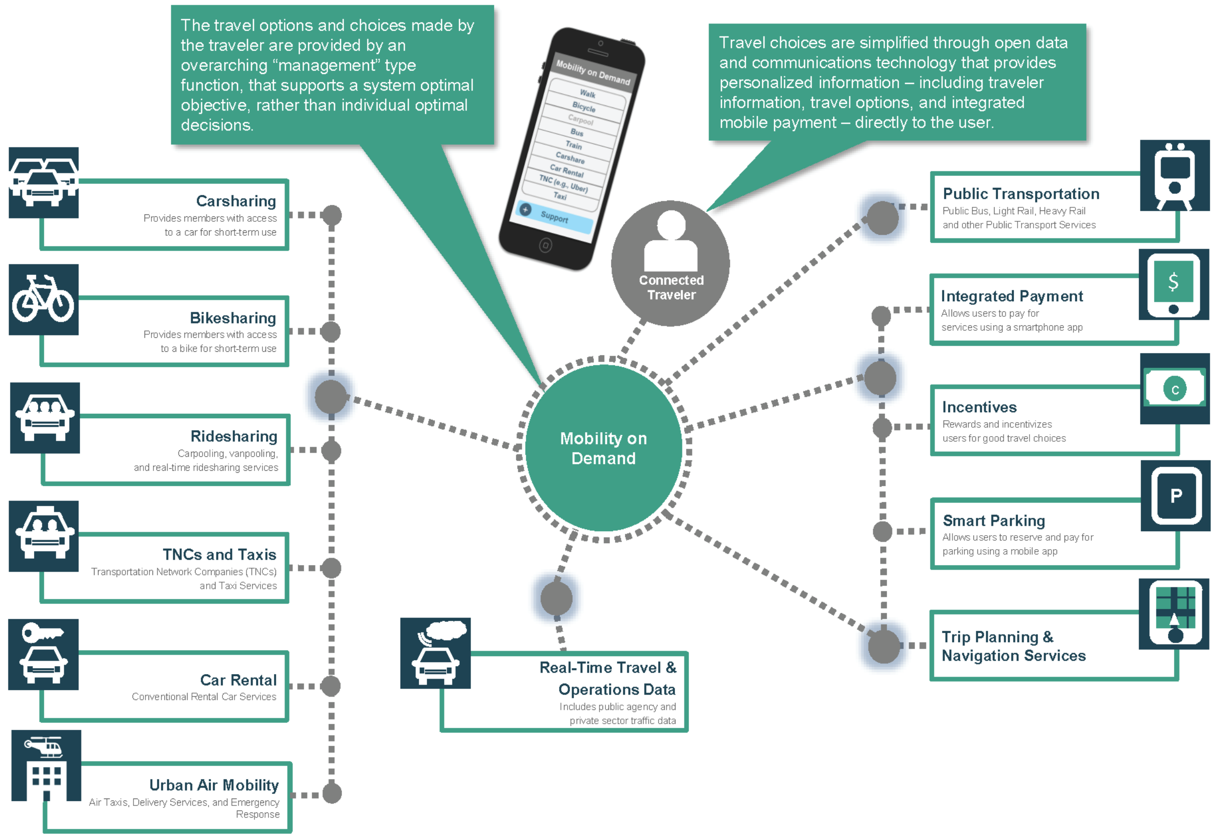

Fig. 1. User-centric travel options.

Source: Adapted from US Department of Transportation.

array of real-time information services.[3] MOD is focused on providing travelers with more seamless travel options (i.e., routing, booking and payment) for all trip segments. This seamless integration improves the user experience and can enable more informed and sustainable transportation choices.

3. What is Mobility as a Service and How Does it Differ from MOD?

MOD differs from another concept, MaaS, in that MOD focuses on the commodification of passenger mobility and goods delivery and transportation systems management, whereas MaaS primarily focuses on passenger mobility aggregation and subscription services. Specifically, MaaS is a new transportation concept that integrates existing and innovative mobility services into one single digital platform where customers purchase mobility service packages tailored to their individual needs (ranging from per trip fares to bundled subscription mobility services).[9] Brokering travel with suppliers, repackaging and reselling it as a bundled package is a distinguishing characteristic of MaaS.

Utriainen and Pöllänen[10] conducted a literature review of MaaS by identifying 37 peer-reviewed journal articles and conference papers. Key characteristics of MaaS identified across this literature include:

1. The integration of traditional and innovative transportation modes (i.e., shared mobility)[11,12];
2. The option for pay-as-you-go and subscription pricing[13];
3. A single platform where users can plan, book, pay and get tickets for their trips[9,14–16];
4. Multiple stakeholders engage in MaaS (customers, service providers, apps, public agencies, etc.)[16–19];
5. The use of information and communications technologies (e.g., smartphone apps)[19–21]; and
6. A customized mobility experience that allows users to modify available trips based on traveler preferences.[15]

Sochor and colleagues[22] established a MaaS typology describing four levels of varying integration: level 0—no integration; level 1—information integration; level 2—booking and payment integration; level 3—service offer integration; and level 4—the integration of societal goals. Sochor

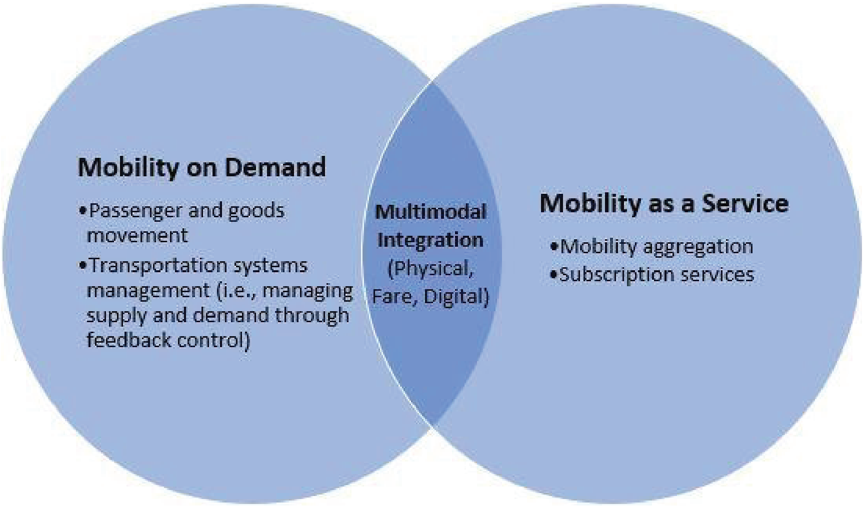

Fig. 2. Similarities and differences of MOD and MaaS.

Source: S. Shaheen and A. Cohen, "Mobility on Demand (MOD) and Mobility as a Service (MaaS). How are they similar and different?" *Move Forward*, 7 March 2019. https://www.move-forward.com/mobility-on-demand-mod-and-mobility-as-a-service-maas-how-are-they-similar-and-different/.

describes level 1 users as primarily travel planners funded through advertising or taxpayer funds. Level 1 service providers aggregate and display data but do not have a fiduciary responsibility to ensure data fidelity. With level 2, service providers integrate trip booking and payment to enhance customer convenience and encourage multimodal travel. For service providers, level 2 grows the potential customer base but also increases potential competition by offering transportation services alongside other service providers. Because level 2 integrates ticketing and payment, data fidelity becomes key. Level 3 is intended to serve as a comprehensive alternative to private vehicle ownership by bundling transportation services together and offering subscription packages. According to Sochor and colleagues[22], level 3 emphasizes meeting a household's complete mobility needs, rather than a single trip between an origin and destination. Level 4 adds value by employing incentives, gamification and other policies to impact traveler choices and influence societal and environmental outcomes. Sochor and colleagues[22] conclude that lumping all MaaS services under a single loosely defined concept can create confusion and possibly undermine the intended concept, thereby necessitating a framework to blend technological and institutional integration of MaaS services.

In summary, the MaaS literature generally concludes that MaaS is a concept about integrating multiple transportation modes into a seamless user experience, requiring open data and cooperation by public and private transportation stakeholders.

MaaS is primarily focused on mobility aggregation and subscription services for passenger mobility options where MOD leverages passenger mobility and goods delivery services to enhance access while simultaneously leveraging MOD to achieve transportation system operational improvements by helping agencies balance supply and demand to match changing conditions across the transportation network.[23]

With MOD, public agencies have the potential to:

- 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[3];
- Improve the efficiency of the transportation system (including energy efficiency) and increase the accessibility and mobility of all travelers[3];
- Enable transportation system operators and their partners to monitor, predict and influence conditions across an entire mobility ecosystem and for an entire region[3]; and
- Receive data inputs from multiple sources and provide response strategies geared to various operational objectives.[3]

MOD has three major guiding principles: (1) traveler centric and consumer driven, (2) data connected and platform independent, and (3) multimodal and mode agnostic.[3] 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.

4. The MOD Ecosystem

Figure 3 demonstrates how MOD can interact and influence supply and demand of the transportation network. Leveraging big data, 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.[3,4] The components of the supply and demand

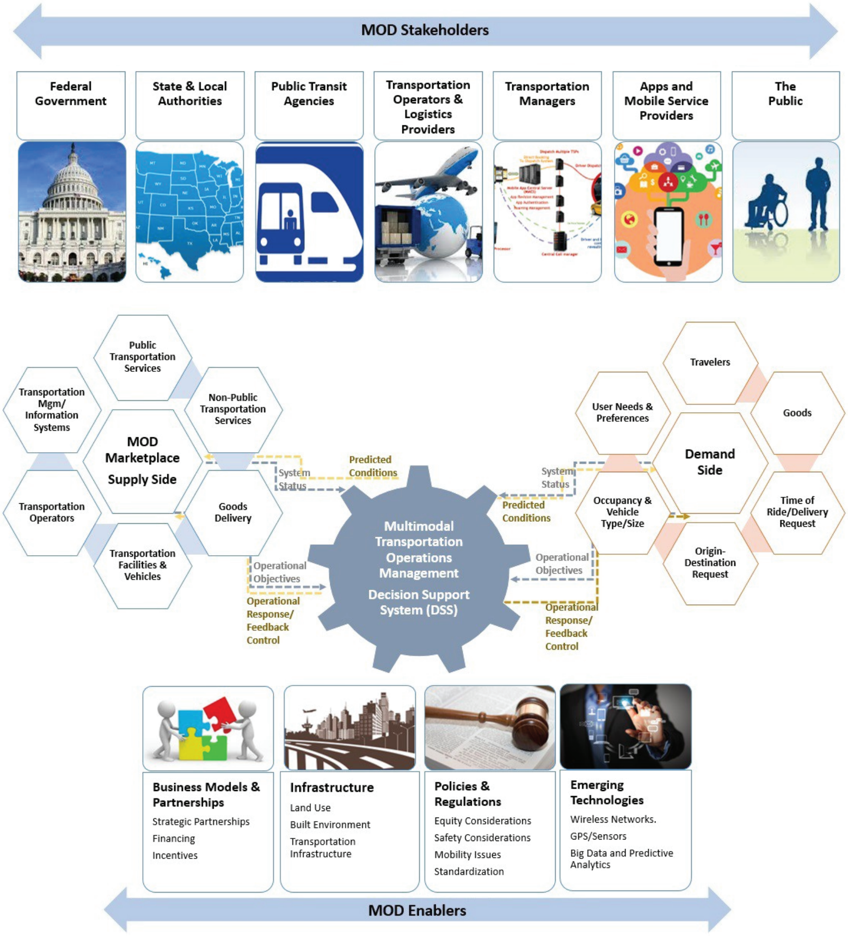

Fig. 3. Supply and demand sides of MOD ecosystem.

Source: S. Shaheen, A. Cohen, B. Yelchuru and S. Sarkhili, *Mobility on Demand Operational Concept Report* (US Department of Transportation, Washington, 2017).

side are based on the concept of consumption choice and trip generation. The supply side of this ecosystem consists of all the players, operators and devices that provide transportation services for people or goods delivery including:

- Public transportation services;
- Non-public transportation services including: bikesharing, carpooling, car rentals, carsharing, microtransit, TNCs, scooter sharing, taxis and other private mobility suppliers;

- Goods delivery services including freights, logistics, first-and-last mile goods delivery, courier network services, drones and robotic delivery;
- Transportation facilities including parking, tolls, roadways and highways;
- Vehicles of all types such as public transit vehicles, private vehicles, goods delivery vehicles and emergency vehicles that could be connected and automated;
- Transportation management and information systems such as payment systems for parking, tolling and public transit, signal systems, mobile apps for trip planning and payment (for all travelers), fleet management systems, and navigation systems; and
- Public and private transportation information services including schedule information, 511 and dynamic message signs, Google maps, etc.

The demand side of this ecosystem consists of all the system users (travelers and couriers) and their choices and preferences including:

- Pedestrians, riders, drivers, cyclists (reflecting the wide spectrum of demographic users, including older adults, people with disabilities, children, etc.);
- Goods and merchandise requiring physical delivery;
- Time of ride and/or delivery request;
- Origin-destination request, which determines the location of the demand and affects the route and mode choice;
- Modal demand based on occupancy, size or type of vehicle requested; and
- User needs and preferences including mode and decision choices on how a trip is made (such as decisions to drive alone, carpool, use public transport, or some other form of shared mobility options).

There is a wide range of modal stakeholders that enable MOD.[3] Common MOD stakeholders include:

- Federal government agencies that play a role in establishing transportation strategies, policies and legislation;
- State and local authorities including municipalities and metropolitan planning organizations (MPOs) that 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, such as city buses, trolley buses, trams (or light train), rapid transit (metro, subway), ferries and paratransit;
- Transportation and traffic managers, including transportation management centers that monitor the operations, allocate resources as necessary and respond to network needs;
- MOD, transportation and logistics service providers that offer mobility and/or delivery services;
- Apps and mobile service providers that enable on-demand mobility and delivery (e.g., mobile ticketing, payment, navigation services, etc.); and
- MOD consumers.

5. Mobility and Delivery Services

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 services 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 services for people including individuals 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).[3,23] In particular, shared mobility service providers and goods delivery services are important enablers of the commodified marketplace because they create a larger user pool and modal options that create a "network effect" where modal options are in closer proximity to one another (physical and digital), adding collective value.[7] Together, MOD can unlock a "multimodal multiplier" effect where intermodal synergies are greater together than the sum of the parts. The next two sections explore the shared mobility and goods delivery marketplaces, which represent the core MOD enablers of the MOD supply side.

5.1. *Shared mobility*

Shared mobility — the shared use of a vehicle, bicycle or other travel mode — is an innovative transportation strategy that enables users to have short-term access to a transportation mode on an as-needed basis. Shared mobility includes a number of transportation modes and service models to meet diverse traveler needs. Shared mobility can include roundtrip services (a vehicle, bicycle or other mode is returned to its origin), one-way station-based services (vehicle, bicycle or mode is returned to a different designated station location), and one-way free-floating services (vehicle, bicycle or mode can be returned anywhere within a geographic area).[1,24] Shared mobility modes comprising the MOD ecosystem include:

1. **Bikesharing:** Provides users with on-demand access to bicycles at a variety of pick-up and drop-off locations for one-way (point-to-point) or roundtrip travel. Bikesharing fleets are commonly deployed in a network within a metropolitan region, city, neighborhood, employment center, and/or university campus.[25,26] Bikesharing typically includes one of three common service models:
   a. Station-based bikesharing systems where users access bicycles via unattended stations offering one-way station-based service (i.e., bicycles can be returned to any station).
   b. Dockless bikesharing systems where users may check out a bicycle and return it to any location within a predefined geographic region. Dockless bikesharing can include business-to-consumer or peer-to-peer systems enabled through third-party hardware and applications.
   c. Hybrid bikesharing systems where users can check out a bicycle from a station and end their trip either returning it to a station or a non-station location, or users can pick up any dockless bicycle and either return it to a station or any non-station location.
2. **Carsharing:** Individuals gain the benefits of private-vehicle use 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 and at public transit stations, employment centers, and colleges and universities. Typically, the carsharing operator provides gasoline, parking and maintenance. Generally, participants pay a fee each time they use a vehicle.[27]

3. **Microtransit:** Privately or publicly operated, technology-enabled transit services that typically employ multi-passenger/pooled shuttles or vans to provide on-demand or fixed-schedule services with either dynamic or fixed routing.[24]
4. **Personal Vehicle Sharing:** Sharing of privately owned vehicles where companies broker transactions among car owners and renters by providing the organizational resources needed to make the exchange possible (e.g., online platform, customer support, driver and motor vehicle safety certification, auto insurance, technology). This is often referred to as peer-to-peer carsharing.
5. **Transportation Network Companies (TNCs):** TNCs (also known as ridesourcing and ridehailing) provide prearranged and on-demand transportation services for compensation, which connect drivers of personal vehicles with passengers. Smartphone applications are used for booking, ratings (for both drivers and passengers) and electronic payment.[1, 24]
6. **Ridesharing:** Ridesharing (also known as carpooling and vanpooling) facilitates formal or informal shared rides between drivers and passengers with similar origin-destination pairings.[1,24]
7. **Scooter Sharing:** Users gain the benefits of a private scooter without the costs and responsibilities of ownership. Individuals typically access scooters by accessing a fleet of scooters at various locations. Scooter operators typically provide power or gas (as appropriate), maintenance and may provide parking. Participants pay a fee each time they use a scooter.[1,24,26] Trips can be roundtrip or one-way. Scooter sharing includes two types of services:
   a. Standing electric scooter sharing using shared scooters with a standing design including a handlebar, deck and wheels propelled by an electric motor. At present, the most common scooters are made of aluminum, titanium and steel.
   b. Moped-style scooter sharing using shared scooters with a seated-design, is electric or gas powered, and generally having a less stringent licensing requirement than motorcycles designed to travel on public roads.
8. **Taxis:** Taxi services provide prearranged and on-demand vehicle services for compensation through a negotiated price, zone pricing or a taximeter. Trips can be made by advance reservations (booked through a phone, website or smartphone application), street hail (by

raising a hand or standing at a taxi stand or specified loading zone), or e-Hail (dispatching a driver using a smartphone application).[1,24]

9. **Urban Air Mobility:** Urban air mobility (UAM) entails air passenger and cargo transportation, including small package delivery and other urban Unmanned Aerial Systems (UAS) services that support a mix of onboard, ground-piloted and autonomous operations.[28,29]

5.2. *Urban goods delivery*

Urban goods delivery is equally important to MOD as changing consumer patterns disrupt traveler behavior. In recent years, innovative technologies and business models are helping to reimagine service delivery. Whether it is a startup (e.g., Uber Eats, Postmates, DoorDash), an internet-based retailer (e.g., Amazon), or a supply chain and logistics firm, advancements in courier services (technologies and service models) are transforming consumer behavior and disrupting supply and trip chains (e.g., linking a series of destinations in one single-origin based trip). Travelers' decision to change their consumption preferences from driving to the store on the way home from work to having their goods delivered will likely drive fundamental changes in traditional travel behavior.[3]

On-demand courier services have grown rapidly due to technology advancements, changing consumer patterns and a growing consumer recognition that goods delivery can serve as substitutes for personal trips to access goods and services. Together these trends have transformed the retail sector from a "just in time" inventory, where retailers order inventory and stock shelves on an as-needed basis to "just in time delivery", with goods delivered directly to consumers on-demand.[30] In recent years, subscription e-commerce has grown exponentially led by many models such as: (1) Dollar Shave Club and Ipsy cosmetics, (2) Stitch Fix fashion on-demand, (3) meal kit delivery services including Blue Apron, Hello Fresh, and Home Chef, and (5) grocery delivery services such as AmazonFresh, Postmates and Instacart. This also includes shipping subscription services, such as ShopRunner and Amazon Prime, that offer unlimited priority delivery services for a flat monthly or annual fee. Even companies, such as Wayfair, are offering free shipping on most merchandise, even larger items (e.g., furniture).[3,30] Advanced algorithms are often employed to aid merchants and delivery providers optimize the supply and delivery chain, ranging from order fulfillment to identifying the least expensive or quickest delivery route. Six innovations in goods delivery that are impacting the MOD ecosystem include:

1. **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.
2. **Locker Delivery:** Locker delivery, which is already widely deployed by the US Postal Service, allows consumers to order and ship items 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).
3. **Courier Network Services (CNS):** Apps or online platforms employed to provide for-hire delivery services for monetary compensation. The apps match couriers — who use a personal vehicle, bicycle, or scooter for deliveries — with customers of the ordered goods (i.e., packages, food).
4. **Drones:** A delivery drone is a short-range unmanned aerial vehicle (UAV) that can transport small packages, food or other goods. Some service providers, such as the United Parcel Service, have experimented with pairing drones and truck-based delivery to improve service delivery.
5. **Robotic Delivery:** Like drones, delivery robots offer short-range unmanned ground-based delivery of packages, food or other goods.
6. **Automated Vehicles (AVs):** Automated and connected vehicles offer another mechanism for future delivery options employing both business-to-consumer and peer-to-peer delivery services. Increasingly, last-mile delivery is being reimagined through automated processes. In Summer 2018, Kroger began testing driverless grocery deliveries in Arizona using AVs. Numerous companies, such as Dispatch and Starship, are delivering food, beverages, parcels and other items using small delivery robots. To accept delivery when a person is at work or away, numerous companies are developing innovations to facilitate secure parcel delivery methods that could be used in conjunction with human couriers, AVs, or both. A few of these innovations include:
   a. ParcelHome, an electric lockbox that can securely send and receive parcels with any courier service;
   b. Pharme, which enables the delivery of packages to the trunk of a car; and
   c. Amazon Key that enables vehicle trunk and in-home deliveries.

Together the growth of e-commerce, subscription services and last-mile delivery may contribute to a dramatic increase in goods-related trips across the entire transportation network.[30] However, it is not just the growth of e-commerce, subscription services and last-mile delivery that has the potential to increase delivery trips. In an automated future, there could be an increasing number of marketplace players including startups, courier services and retailers (who may more readily opt to operate their own delivery fleets). Goods delivery innovations within the MOD ecosystem have the potential to disrupt both businesses (e.g., retail) and daily travel behavior (e.g., induced demand, congestion).[3,30]

6. MOD Business Models

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) peer-to-peer (P2P).[1,3] There can be overlap among business models due to variations in the services provided, ownership, administration and operational characteristics.

B2C services provide individual consumers with access to a business owned and 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. B2G offers transportation services to a public agency. Pricing may include a fee-for-service contract, per-transaction basis or some other pricing model. B2B services sell 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. P2P services broker mobility and courier transactions among car, bicycle or other device owners and renters by providing the organizational resources needed to make the exchange possible (i.e., online platform, customer support, driver and motor vehicle safety certification, auto insurance and technology).[1,3]

7. Technology as an Enabler: The Role of Data and Smartphone Apps in MOD

Digitization of the transportation network — from real-time analytics, mobile applications, sensors and satellite navigation — allows travelers to be more informed, agile and mobile in their transportation decisions.

Leveraging data and real-time analytics at all stages of the traveler process is a key MOD enabler. Data understanding can aid public agencies and transportation operators (public and private) build a more intelligent, responsive and agile transportation network.[2,3]

The dramatic increase in intelligent transportation systems, location-based services wireless and cloud technologies, coupled with the growth of data, are driving fundamental changes in consumer behavior. First, end users are employing mobile websites and apps for an array of transportation functions, such as vehicle routing and parking, information services, trip planning, fare payment and goods delivery.[2,3] Four types of mobile services are impacting consumer and traveler behavior. These include:

- **Mobility services** that assist users with routing, booking and payment of single and multimodal trips. This can include shared mobility, public transit apps, real-time information apps, taxi e-Hail and multimodal aggregators;
- **Courier network services** offering for-hire paid delivery for monetary compensation by employing an online application to connect couriers using private vehicles, bicycles, scooters or other equipment with light cargo;
- **Vehicle connectivity services** that provide vehicle diagnostic information and enable remote access and dispatch emergency services (e.g., accident and roadside assistance, unlocking a vehicle); and
- **Smart parking services** that deliver information on parking costs and availability. This includes "e-Parking" services to reserve and pay for parking and "e-Valet" services that connect vehicle owners to valet drivers to pick-up, park, charge or refuel, and return vehicles.

Additionally, real-time data analytics and algorithms are being used in a variety of ways to: (1) improve traveler experience, (2) enhance operations (such as managing crowdsourced and flexible routing), (3) provide predictive analytics to more accurately forecast and respond to demand, and (4) improve operational responses with natural or manmade hazards impacting usual transportation operations.[2,3,31]

Growing consumer use of digital services, coupled with real-time data analytics and algorithms, are creating vast amounts of data that will enable travelers, transportation providers and public agencies to make smarter, more intelligent and efficient transportation decisions.[2,3,31] While transportation service providers, such as public transit and TNCs use a variety of data and data sources in their modeling and operations, big data and data sharing have the potential to enhance transportation planning and traveler services by empowering operators and policymakers to better understand the current state of the transportation network and more accurately identify services gaps and respond through immediate service adjustments and longer-term infrastructure improvements.[31]

Equally important and possibly more transformative, data collection and processing are key to deploying driverless vehicles in the MOD ecosystem.[3,4,31] Generally, data are used in three key contexts to enable shared AVs (SAVs):

1. Machine learning algorithms predict outcomes based on large volumes of data;
2. Vehicle computers must process detailed maps and other data of the entire street and adjacent environment; and
3. Vehicles should communicate with other vehicles and infrastructure to share data.

As such, machine learning, artificial intelligence, big data management and other technologies can be key enablers to connect travelers, goods, services and infrastructure as well as automating MOD vehicles.

8. MOD and Driverless Vehicles

In the future, automation could be one of the most transformative trends to impact MOD and the broader transportation ecosystem. Vehicle automation will likely result in fundamental changes to cities and the transportation ecosystem by altering the built environment, costs, commute patterns and modal choice. In an AV future, transportation could change cities in four fundamental ways:

1. The density of urban centers could increase, as SAVs impact reliance on private vehicle ownership and use. Even if privately owned AVs would no longer need to be parked in a city's highest valued real estate. Instead, these vehicles could self-drive and park away from residential, employment and other activity centers.[7] As such, auto-oriented land uses, such as parking, gas stations and auto dealerships, could be redeveloped into housing, offices and other land uses following the principles of the highest and best use. The four criteria guiding the highest and best use of real estate are: (1) legal permissibility, (2) physical possibility, (3) financial feasibility, and (4) maximum productivity.

2. Suburban and exurban areas are likely to expand, particularly in regions with high costs of living that lack affordable housing. With the growth of telecommuting, fewer work days in the office and AVs, longer commutes could become less of an impediment. Vehicle automation has the potential to transform commutes from lost driving time into productive hours that could be spent working, relaxing or resting. For these reasons, there could be a bifurcation in the built environment and modal choice, where urban centers become denser with greater adoption of shared modes, and suburban and exurban areas become more sprawling with continued reliance on privately owned (now automated) vehicles.[3,7]

3. A reduction in parking is likely, although estimating the reduction amount is difficult and will likely be regionally based on AV ownership rates, the built environment and walkability of a city, and the availability of high-quality public transportation and on-demand mobility options. Parking is a very expensive addition to most real estate projects, and the vast majority is unpaid with a limited return on the investment. A reduction in parking demand can free up land and capital to make other property improvements, such as increased density and public spaces.[32]

4. Automation will likely change the operations and competitiveness of public transportation, although the precise impacts (positive or negative) are unknown. Reduced vehicle ownership due to SAVs could result in changes in parking needs, particularly in urban centers. The repurposing of urban parking has the potential to create new opportunities for infill development and increased densities. While SAVs may compete with public transit ridership, infill development could also create higher densities to support additional public transit ridership and allow for the conversion of bus transit to rail transit in urban cores. As such, concerns that the introduction of AVs could reduce demand for public transit and may encourage increased vehicle use are real.[7] Just as AVs have the potential to reduce driving costs, automated transit vehicles have the opportunity to reduce operating costs and the potential to pass savings on to riders in the form of lower fares. Reduced operational costs and lower fares could make public transit more competitive than other modes and result in increased ridership.[7]

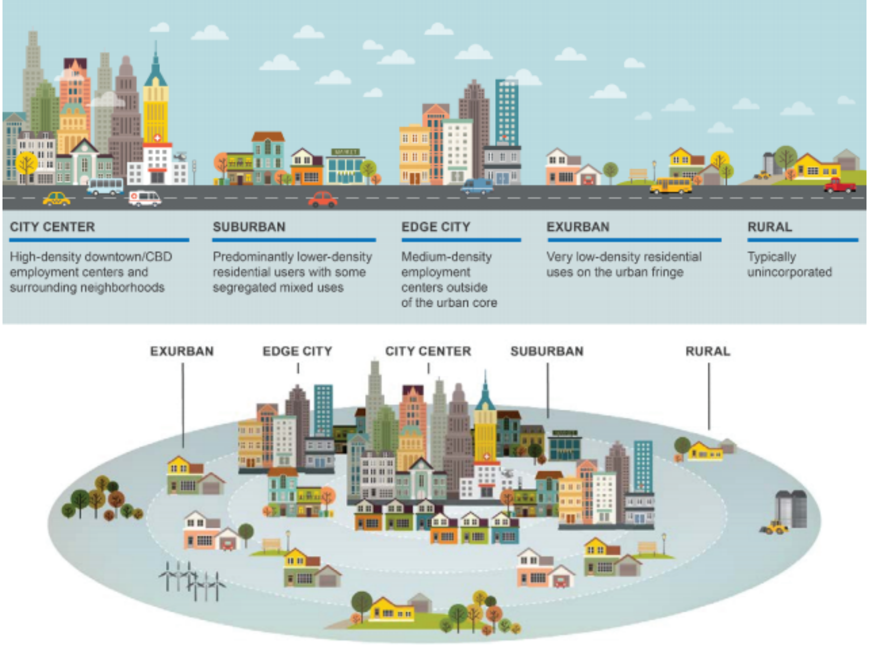

Fig. 4.

Source: S. Shaheen, A. Cohen, B. Yelchuru and S. Sarkhili, *Mobility on Demand Operational Concept Report* (US Department of Transportation, Washington, 2017).

9. Conclusions

MOD is evolving and reshaping mobility. It is 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 differs from MaaS because MOD emphasizes the concept of transportation as a commodity, whereas MaaS focuses on integrating existing and innovative mobility services into one single digital platform where customers purchase mobility service packages tailored to their individual needs. The MOD ecosystem is comprised of numerous public and private stakeholders, such as mobility and delivery service providers that influence the supply and demand of the transportation system. Information technology, such as real-time data and smartphone apps, coupled with innovative business models are important enablers of MOD.

While the impacts of vehicle automation on MOD are uncertain, the convergence of mobility services, shared modes, electrification and automation could transform how people travel, how cities are designed and built, and the ways in which consumers access goods and services. As emerging technologies become more mainstream policymakers will need to rethink traditional notions of access, mobility and auto mobility. While increased use of multi-passenger vehicles and optimized routing could greatly increase efficiency, lower costs and improved accessibility could offset these gains due to induced demand, which could result in a net increase in energy use and emissions. Moving forward, it will be critical to balance public goals, commercial interests and technological innovation to harness and maximize the social and environmental benefits of next generation mobility systems.

References

1. S. Shaheen, A. Cohen and I. Zohdy, *Shared Mobility: Current Practices and Guiding Principles* (US Department of Transportation, Washington, 2016).
2. S. Shaheen, A. Cohen, I. Zohdy and B. Kock, *Smartphone Applications to Influence Travel Choices: Practice* (US Department of Transportation, Washington, 2016).
3. S. Shaheen, A. Cohen, B. Yelchuru and S. Sarkhili, *Mobility on Demand Operational Concept Report* (US Department of Transportation, Washington, 2017).
4. S. Shaheen, A. Cohen, M. Dowd and R. Davis, *A Framework for Integrating Transportation into Smart Cities: State of the Practice in 20 US Cities* (Mineta Transportation Institute, San Jose, 2019).
5. S. Shaheen, A. Cohen and E. Martin, *The US Department of Transportation's and the Federal Transit Administration's Mobility on Demand Sandbox* (US Department of Transportation, Washington, 2017).
6. S. Shaheen and A. Cohen, *Mobility on Demand: Three Key Components*, 27 February 2018. https://www.move-forward.com/mobility-on-demand-three-key-components/
7. S. Shaheen and A. Cohen, "Is it time for a public transit renaissance? Navigating travel behavior, technology, and business model shifts in a brave new world", *Journal of Public Transportation*, 2018, pp. 67–81.
8. A. Durand, L. Harms, S. Hoogendoorn-Lanser and T. Zijlstra, *Mobility-as-a-Service and Changes in Travel Preferences and Travel Behaviour: A Literature Review* (KiM Netherlands Institute for Transport Policy Analysis, Amsterdam, 2018).

9. S. Hietanen, "Mobility as a service: The New Transport Paradigm", *ITS & Transport Management Supplement. Eurotransport*, 2014, pp. 2–4. http://fsr.eui.eu/wp-content/uploads/150309-1-Hietanen-1.pdf
10. R. Utriainen and M. Pöllänen, (2017). "Review on mobility as a service in scientific literature". *Conference Proceedings, 1st International Conference on Mobility as a Service* (*IcoMaaS*), Tampere University of Technology, Tampere, 28 to 29 November 2017, pp. 141–155.
11. A. Melis, S. Mirri, C. Prandi, M. Prandini, P. Salomoni and F. Callegati, "Integrating personalized and accessible itineraries in MaaS ecosystems through microservices", *Mobile Networks and Applications*, 2018, pp. 167–176.
12. A. Melis, M. Prandini, L. Sartori and F. Callegati, "Public transportation, IoT, trust and urban habits", in *Public Transportation, IoT, Trust and Urban Habits* (Springer International Publishing AG, Cham, 2016).
13. K. Pangbourne, M. Mladenovic, D. Stead and D. Milakis, "The case of Mobility as a Service: a critical reflection on challenges for urban transport and mobility governance", in *Governance of the Smart Mobility Transition* (Bingley: Emerald Group Publishing, Bingley, 2017), pp. 33–48.
14. G. Ambrosino, J. Nelson, M. Boero and I. Pettinelli, "Enabling intermodal urban transport through complementary services: from flexible mobility services to the shared use mobility agency: workshop 4. Developing intermodal transport systems", *Research In Transportation Economics*, 2016, pp. 179–184.
15. D. Hensher, "Future bus transport contracts under a mobility as a service (MaaS) regime in the digital age: are they likely to change?" *Transportation Research Part A: Policy and Practice*, 2017, pp. 86–96.
16. M. Kamargianni, W. Li, M. Matyas and A. Schäfer, "A critical review of new mobility services for urban transport", *Transportation Research Procedia 1*, 2016, pp. 3294–3303.
17. M. Kamargianni and M. Matyas, "The Business Ecosystem of Mobility-as-a-Service", *Transportation Research Record: Journal of the Transportation Research Board*, 2017.
18. H. Ozaki, "Technical standardization of ITS and Asian initiatives for intelligent mobility", *IATSS Research*, 2018, pp. 72–75.
19. A. Melis, "Responding to climate change: lessons from an Australian hotspot", *Urban Policy and Research*, 2017, pp. 114–115.
20. T. Hilgert, M. Kagerbauer, T. Schuster and C. Becker (2016). "Optimization of individual travel behavior through customized mobility services and their effects on travel demand and transportation systems", *Transportation Research Procedia*, 2016, pp. 58–69.
21. P. Jittrapirom, V. Caiati, A.-M. Feneri, S. Ebrahimigharehbaghi, M. Alonso González and J. Narayan, "Mobility as a service: a critical review of definitions, assessments of schemes, and key challenges", *Urban Planning*, 2017.

22. J. Sochor, H. Arby, M. Karlsson and S. Sarasini, "A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of societal goals", *Research in Transportation Business & Management*, 2018, pp. 3–14.
23. S. Shaheen and A. Cohen, "Mobility on Demand (MOD) and Mobility as a Service (MaaS). How are they similar and different?" *Move Forward*, 7 March 2019. https://www.move-forward.com/mobility-on-demand-mod-and-mobility-as-a-service-maas-how-are-they-similar-and-different/
24. S. Shaheen and A. Cohen, *Planning for Shared Mobility* (The American Planning Association, Chicago, 2016).
25. S. Shaheen, E. Martin, N. Chan, A. Cohen and M. Pogodzinski, *Public Bikesharing in North America During A Period of Rapid Expansion: Understanding Business Models, Industry Trends, and User Impacts* (Mineta Transportation Institute, San Jose, 2014).
26. S. Shaheen and A. Cohen, "Shared micromobility policy toolkit", March 2019. http://doi:10.7922/G2TH8JW7
27. S. Shaheen, A. Cohen and D. Roberts, "Carsharing in North America: market growth, current developments, and future potential", *Transportation Research Record*, 2005.
28. S. Shaheen, A. Cohen and E. Farrar, *The Potential Societal Barriers of Urban Air Mobility* (*UAM*) (National Aeronautics and Space Administration, Washington, 2018).
29. National Aeronautics and Space Administration, "NASA embraces urban air mobility, calls for market study", National Aeronautics and Space Administration. https://www.nasa.gov/aero/nasa-embraces-urban-air-mobility
30. S. Shaheen and A. Cohen, "Seven goods delivery innovations: transforming transportation & consumer behavior", *Move Forward*, 12 Decmber 2018. https://www.move-forward.com/seven-goods-delivery-innovations-transforming-transportation-consumer-behavior/
31. S. Shaheen and A. Cohen, "Big data, automation, and the future of transportation", *Meeting of the Minds*, 25 July 2017. https://meetingoftheminds.org/big-data-automation-future-transportation-22106
32. S. Shaheen and A. Cohen, "Managing the transition to shared automated vehicles: building today while designing for tomorrow", *Meeting of the Minds*, 21 May 2018. https://meetingoftheminds.org/managing-the-transition-to-shared-automated-vehicles-building-today-while-designing-for-tomorrow-2-27094