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Universal Mobility as a Service:

A Bold Vision for Harnessing the Opportunity of Disruption

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Foreword

This is the core paper in a series titled *The Future of Transportation: The Opportunity (and Potential Pitfalls) of Disruptive Technology*. It articulates a vision for transportation in America centered on the concept of Universal Mobility as a Service, where everyone in the community is served regardless of age, disability, race/ethnicity, income, or geographic location.

The concept presents a once-in-a-lifetime opportunity to help shape the future of our transportation system. Its focus is on ensuring that the disruptive technologies emerging today can be molded to vastly increase mobility for older adults and other currently disenfranchised users of the transportation system.

While autonomous vehicles have received ample attention in the media, the impending disruption is much larger than the introduction of this technology and could involve a shift in the entire ecosystem of transportation. Looking at transportation holistically as the ecosystem that it is and will be, Universal Mobility as a Service, when aligned with a commitment to livable communities, provides a framework to manage the disruptive forces and lead to a more equitable and sustainable transportation future.

While this paper discusses autonomous vehicles along with other emerging technologies, it does not intend to be an exhaustive look at the policy considerations necessary for the safe introduction of autonomous vehicle technology into community transportation systems. The author recognizes, and even underscores, that numerous issues related to safety, liability, cybersecurity, and labor must be addressed. Several organizations are exploring these issues. The AARP Public Policy Institute may also explore them in more depth at a future point in time.

Summary

Mobility as a Service describes a shift away from personally owned modes of transportation (i.e., car ownership) and toward mobility solutions consumed as a service. Universal Mobility as a Service expands on this concept to offer customers a single platform to efficiently identify all available transportation options, compare cost, schedule a ride, and even pay for a trip. Fixed-route and demand responsive public transportation, plus private on-demand options, including ridesourcing, ridesharing, carsharing, and bikesharing, are available to serve everyone in the community. While services tailored to the needs of particular populations will be available, they would be part of a single, coordinated system to meet the needs of everyone in the community regardless of income, race/ethnicity, geographic location, disability, or age. Universal Mobility as a Service, when aligned with a commitment to livable communities, provides a framework to manage disruptive forces and lead to an accessible, fair, and sustainable transportation future.

About the Terminology Used in This Report

Many writers use the terms ***autonomous vehicles, driverless cars***, and ***self-driving cars*** interchangeably. This has caused much confusion for readers trying to understand the development of this disruptive technology. Included is a *Glossary of Terms* at the back of this paper to help the reader understand how these and other terms are used in this *Future of Transportation* paper series by the AARP Public Policy Institute. Terms that appear in the glossary are ***bold-italicized*** in the text of this paper on first use.

About PPI

The AARP Public Policy Institute informs and stimulates public debate on the issues we face as we age. The Institute promotes the development of sound, creative policies to address our common need for economic security, health care, and quality of life.

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The views expressed herein are for information, debate, and discussion and do not necessarily represent official policy of AARP.

References to particular companies and services are provided to illustrate the evolving transportation ecosystem and do not constitute AARP endorsement.

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01 Executive Summary

Emerging disruption in the transportation sector offers a once-in-a-lifetime opportunity to help shape the future of our transportation system. Communities across the United States and the world are on the cusp of a major disruption equivalent in scale to the mobility and social change brought about by the inventions of the steam locomotive and gas-powered automobile.

Autonomous vehicles are a highly publicized aspect of the impending disruption. But the revolution can and may go far beyond that, to one involving not only technology but an entire ecosystem of transportation.

Transportation policy in the United States and infrastructure investment of the past 100 years have resulted in tremendous mobility for many Americans. Still, many are isolated, including more than one in five older adults who do not drive. Further, numerous other negative societal effects have occurred, such as traffic congestion, air and noise pollution, sprawl, and imbalanced economic and social opportunities—an imbalance skewed against many people who have low income or have disabilities.

Despite the more than 100 million nondrivers in the United States today (one-third of the US population), the transportation systems of most communities require people to drive to have full access to the economic and social life of their communities. The impending transportation revolution offers potential to change that. To harness the coming seismic transportation shifts for maximum benefit, citizens must play an active role in shaping policy rather than sitting back and watching what unfolds.

To date, industry has offered two Mobility as a Service (MaaS) concepts. At its most basic, MaaS describes a shift away from individually operated transportation (i.e., car ownership) toward a menu of services provided to consumers on demand. More broadly, much like a search engine that return flight options for multiple carriers (e.g., Expedia), MaaS would be a single platform that offers real-time information with an easy payment system for fixed-route, on-demand transit and other travel options. Customers would access this platform to identify available transportation options, evaluate costs and timing, schedule and pay for a ride, and even receive real-time information about the travel environment.

This paper builds on MaaS by adding the concept of universality. It offers a vision for *Universal* Mobility as a Service (Universal MaaS), which along with a commitment to livable communities, provides a unifying framework to manage disruptive forces and lead to a more accessible, fair, and sustainable transportation future.

This paper's vision of Universal Mobility as a Service expands on basic industry concepts of MaaS to ensure that *all* users' needs are met, regardless of income, geographic location, disability, or age. *Universal* refers to both a comprehensive inclusion of all available transportation services within the platform and accessible design throughout the system. Specifically, Universal Mobility as a Service includes the following:

- Fully integrating specialized transportation within the MaaS framework
- Applying the principles of universal design to all facets of the system
- Fostering shared-use mobility, rather than overreliance on car ownership and solo driving (or riding in the case of autonomous vehicles)
- Offering customers, including those with special needs, a variety of transportation options, along with seamless payment systems, and traveler information
- Integrating fixed-route and demand responsive public transportation, as well as taxi service, ridesourcing (e.g., Lyft and Uber), carpooling, carsharing, bikesharing, and volunteer transportation.


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No smoking
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All parts of this new transportation ecosystem would work together to offer consumers efficient, safe, accessible, and affordable transportation options, and form the foundation for more livable communities. Making this vision a reality to benefit all will take an intentional alignment of policy and collaboration among public- and private-sector players.

Emerging technologies and past experience in providing timely and efficient transportation and customer service can help build Universal Mobility as a Service in both urban and rural America. Public transportation stands poised to continue in its important role and serve as the backbone of Universal MaaS and a new transportation era.

MaaS developers have not typically focused on travelers with special needs, but if carefully designed, MaaS could vastly improve transportation services to this growing population. A Universal MaaS system, where specialized transportation services are integrated into a single platform along with shared-use mobility services, could be smart enough to apply the appropriate subsidy for each unique human services transportation client and trip request, with clear protections of privacy. To accomplish this, all providers' data systems would need to be interoperable. The technology solution exists, but institutional commitment to Universal MaaS is required.

For MaaS to successfully expand mobility options for people with disabilities and older adults who are frail, MaaS developers would need to embrace universal design principles in both customer interaction and vehicle design. While many barriers can be addressed through app and vehicle design, it is important to note the important role of human support in certain instances to complement the technology. Mobility management, as the term is used by social service–oriented professionals, can be a way to bring a human dimension to MaaS. Universal MaaS systems would also need to address income-induced barriers.

MaaS can happen with or without driverless vehicles, but as technology changes the economics of travel, it increases the likelihood that transportation will take the form of on-demand services. Fleets of driverless electric vehicles requiring lower maintenance, energy, finance, insurance, and replacement costs, in combination with much higher vehicle utilization rates, could mean that shared use of electric vehicles would be 4 to 10 times cheaper than buying a new car. One analyst suggests that 95 percent of all US passenger miles will be served by providers that will own and operate fleets of driverless electric vehicles within 10 years of widespread regulatory approval of autonomous vehicles. Others predict the status quo for the foreseeable future, given Americans' demonstrated "love affair" with the car and the fact that car purchase decisions do not always reflect the most economical choice available. While timing of widespread disruption is uncertain, the huge amount of cash flowing into the emerging transportation ecosystem foretells of the inevitability of change.

The United States has an unprecedented opportunity to redesign the transportation system to vastly improve transportation equity. But realizing this aspiration will require foresight and the wherewithal to put in place policies that can both unleash the opportunity of disruptive technologies as well as tame their potential for harm. Positive change is not a given. Introducing driverless technology into the market as a vehicle feature, such as leather seats or alloy wheels, may significantly drive up purchase prices, making mobility unaffordable to many Americans. It could also create or exacerbate problems in ways the public may not expect—for example, it could tax the capacity of the existing road system by enabling owners the option of avoiding parking fees by sending the car around the block or home to be parked for free in the driveway, adding more miles to our already burdened roads. Simply rolling out the technology through privately provided on-demand platforms, as commonly envisioned by automotive and ridesourcing companies, may still not reduce the cost of travel sufficiently for low-income Americans and it promises few benefits for people who depend on an accessible vehicle. Furthermore, pricing on-demand service that would be affordable to today's moderate- and upper-income transit users creates the risk of potentially siphoning an important ridership base, resulting in less revenue, political support, and funding for public transit services. Lower-income travelers have the most to lose from worsening transit service.

It is up to policy makers and their constituents to put in place the requisite policies and regulations that will ensure that private entrepreneurship and innovation within the transportation sector serves the public interest. Collaboration among public and private sectors players is paramount. In a companion paper, the author lays out a dozen building blocks for the road ahead.

Building Blocks for the Road Ahead

1. Embrace a Universal Mobility as a Service framework
2. Prioritize shared use mobility
3. Adopt a strong commitment to equity
4. Maximize independence
5. Commit to universal design
6. Support livable, sustainable communities
7. Foster transportation system efficiency
8. Encourage data system and platform interoperability
9. Put in place a transparent system to measure impacts, both positive and negative
10. Prioritize safety for all modes of travel
11. Provide consumer protections
12. Manage effects of resulting economic shifts, facilitating career transitions

Universal Mobility as a Service is possible.

Many industry leaders suggest that emerging technology and market environments coalesce to make MaaS, at least in its narrowest form, highly likely. If implemented fully and thoughtfully, Universal Mobility as a Service has the potential to lead to a more equitable transportation system, where tens of millions of nondrivers are able to more fully participate in the economic, social, and civic life of their communities.

02 Introduction

Communities across the United States and the world are on the cusp of a major disruption to our transportation system equivalent in scale to the mobility and social change brought about by the inventions of the steam locomotive and gas-powered automobile.

Autonomous vehicles are a highly publicized aspect of the impending disruption.[1] But the revolution can and may go far beyond that, to one involving not only technology but an entire ecosystem of transportation.

The US transportation sector is valued at over $1.6 trillion and its markets are undergoing unprecedented disruption.[2] Auto companies and fleet operators are po-

1 ***Bold-italicized*** terms are defined in the glossary.

2 Bureau of Transportation Statistics, *U.S. Gross Domestic Product (GDP) Attributed to Transportation Functions (Billions of current dollars)*, Table 3-3, 2016. https://www.bts.gov/content/us-gross-domestic-product-gdp-attributed-transportation-functions-billions-current-dollars

sitioning themselves to put autonomous vehicles on the road, and major companies are funneling billions of dollars into technology startups whose hardware and software power such vehicles. Even telecommunications and entertainment companies are in the mix, excited to give passengers something to do en route. A recent Brookings Institute survey found more than 160 deals related to transportation, including investments, partnerships, and acquisitions, worth nearly $80 billion.[3] In the words of Andrew Hawkins, writer for *The Verge*, "Given the huge amounts of cash flowing into this industry, it seems reasonable to assume that this is just the calm before the storm."[4]

In fact, autonomous vehicles are only one piece of the revolution. New technology in this sector is already altering the ways we interact with our transportation system. The relatively recent introduction of smartphone-based ***ridesourcing*** (e.g., Lyft and Uber) and trip-planning apps (e.g., Google Transit and Moovit) have changed how urban Americans move about their cities. Data-sharing specifications under development in 2018 will allow rural and human services providers of ***demand responsive transportation*** to more seamlessly coordinate service across a network of different transportation providers. ***Carshare*** and ***bikeshare*** (including ***dockless***) systems offer new opportunities to get around, while also introducing new challenges. Widespread use of autonomous vehicle technology, including ***delivery robots*** that will share sidewalk space, will further disrupt the travel environment in ways difficult to imagine today.

Each part of this new transportation ecosystem can work together to offer consumers efficient, safe, and affordable transportation options, but it will take conscious alignment of policy to ensure that this transformation benefits all. If improperly implemented, disastrous repercussions for our communities could result, further exacerbating social isolation and economic opportunity, as well as traffic congestion and environmental harms.

3 Cameron F. Kerry and Jack Karsten, *Gauging Investment in Self-Driving Cars* (Brookings Institution, October 16, 2017), https://www.brookings.edu/research/gauging-investment-in-self-driving-cars/.

4 Andrew J. Hawkins, "This Map Shows How Few Self-Driving Cars Are Actually on the Road Today," *The Verge*, 2017, https://www.theverge.com/2017/10/23/16510696/self-driving-cars-map-testing-bloomberg-aspen.

02

The Need for a More Inclusive Transportation System

Chronicling the shortcomings of the current transportation system makes it clear that America is ready for a new transportation paradigm. Many travelers face traffic congestion, potholes, failing rail systems, and streets too dangerous to navigate on foot. Some acquire debt they cannot afford for the purchase of a car because more affordable travel options do not exist in their communities. Many baby boomers are searching for secure transportation for their parents today and hoping it will be there for them tomorrow.[5] Business as usual is not an option.

Transportation policy in the United States and the infrastructure investment of the past 100 years has resulted in tremendous mobility for many Americans. But it has also left many isolated. One-third of US residents do not drive.[6] Nondrivers include children, many people with incomes too low to afford the upkeep of a personal vehicle, more than one in five individuals over the age of 65, many people with disabilities, and others who, for a variety of reasons, choose not to drive. For many, accessing transportation can range from a minor inconvenience to an insurmountable barrier. Many of the 100 million nondrivers in the United States today cannot fully participate in the economic or social life of their communities because they lack transportation.

> More than 100 million Americans do not drive, yet the transportation system of most US communities requires people to drive to have full access to the economic and social life of their communities.

Beyond inadequate transportation options, one of the greatest barriers to mobility for those who do not drive, or who are looking for alternatives to driving, is lack of awareness of available services. Travelers today may not be able to seamlessly move between one mode and another or among different providers. Or they may find it difficult to understand the various costs associated with different services (in terms of both money and time). Different accounts and payment systems may be required. Travelers may not have information at their fingertips to respond quickly to changes in the transportation environment, such as a road closure or rail line delay.

Our current transportation system has led to numerous other negative societal impacts. Those felt most acutely are traffic congestion, air and noise pollution, sprawl, and imbalanced economic and social opportunities for many people who have disabilities or have low income. Some people are unable to hold a job because of transportation problems.[7] Others who can no longer drive safely are left without adequate transportation options when they have to hang up their car keys. Indeed, the typical 70-year-old has 7–10 years at the end of life when he or she no longer drives and transportation alternatives become essential.[29] Most communities lack adequate mobility options for people at this life stage. And at least 3.6 million Americans miss medical appointments every year due to a lack of transportation.[8,9]

Meanwhile, urban sprawl, fueled in part by access to the interstate highway system, has consumed farmland and open space and contributed to a decline in exercise opportunities,

5 Joseph F. Coughlin and Lisa A. Ambrosio, Aging America and Transportation: Personal Choices and Public Policy (New York: Springer Publishing Company, 2012); Helen K. Kerschner and Nina M. Silverstein, Introduction to Senior Transportation (New York: Routledge, Taylor & Francis, 2018).

6 AARP Public Policy Institute calculations based on driving status by age and gender using Highway Statistics 2016 (Federal Highway Administration) and 2016 Population Estimates (US Census Bureau).

7 AARP Public Policy Institute analysis based on 2007-2017 Basic Monthly CPS - http://thedataweb.rm.census.gov/ftp/cps_ftp.html#cpsbasic

8 Richard Wallace, Paul Hughes-Cromwick, Hillary Mull, Snehamay Khasnabis, "Access to Health Care and Nonemergency Medical Transportation: Two Missing Links," Transportation Research Record: Journal of the Transportation Research Board volume no. 1924 (2005): 76–84.

9 Henry Claypool, Amitai Bin-Nun, and Jeffrey Gerlach, "Self-Driving Cars: The Impact on People with Disabilities," Ruderman Family Foundation and Securing America's Future Energy, January 2017. This Ruderman Family Foundation White Paper estimates that more than 11 million medical appointments are missed annually by individuals with disabilities and chronic conditions due to inadequate transportation and that at least $19 billion could be saved annually through improved access to medical care for individuals ages 18 to 64, mostly from public entitlement programs.

10 Active transportation typically refers to walking and biking. See glossary.

29 Daniel J. Foley, Harley K. Heimovitz, Jack M. Guralnik, Dwight B. Brock, "Driving Life Expectancy of Persons Aged 70 Years and Older in the United States," American Journal of Public Health, Vol.92, No. 8, August 2002.

as many people no longer live close enough to reach destinations on foot or bike, while roads linking key destinations are not designed for safe ***active transportation***.[10] The result is a system ripe for reform, at a time when the transportation system itself is primed for transformative change as new emerging technologies are being quickly introduced into our transportation system.

02

Current Disruption Offers an Unprecedented Opportunity

Emerging disruptive technologies present an unprecedented opportunity to vastly expand mobility for all sectors of society and address the adverse impacts of our transportation system. But realizing these aspirations will require foresight and the wherewithal to put in place policies that can both unleash the opportunity and tame its potential for harm. Simple one-to-one replacement of our human-driven personal vehicles with driverless vehicles would miss this once-in-a-lifetime opportunity and could risk even greater transportation, social, and environmental challenges for our communities.

Individuals' mobility needs change with life stage. At the beginning and often toward the end of life, people are most dependent, but the goal should be to maximize independence as early and for as long as possible. Without adequate alternatives, school-aged children and adult nondrivers rely on family and friends for transportation. Areas with public transportation and more tailored services can foster independence.

Transportation planning today is typically focused on the needs of the work commuter. Often, planning for roads and public transportation are carried out in separate silos. Planning for safe pedestrian and bicycle travel is still too often an afterthought. Addressing the travel needs of those with disabilities and mobility limitations is often relegated from transportation planning offices to less-resourced human service agencies. The emerging disruption to the transportation sector creates a unique opportunity for all sectors to come together to plan a transportation system that serves everyone.

To date, industry has offered two ***Mobility as a Service*** (MaaS) concepts underlying this disruption. At its most basic, MaaS describes a shift away from individually operated transportation (i.e., car ownership) toward a menu of services provided to consumers *on demand*. More broadly, much like a search engine that provides flight options for multiple carriers, MaaS would be a single platform that offers real-time information with an easy payment system for fixed-route, on-demand transit and other travel options. Customers would access this platform to identify available transportation options, evaluate costs and timing, schedule and pay for a ride, and even receive real-time information about the travel environment.

> This paper builds on the concept of MaaS by adding the element of universality. It offers a vision for *Universal Mobility as a Service (Universal MaaS)*, which when aligned with a commitment to livable communities would provide a unifying framework to manage disruptive forces and lead to more equitable, accessible, and sustainable transportation.

03 Universal Mobility as a Service

Industry Precursors to Universal Mobility as a Service

With new technology, systems, and even different views of transportation emerging, America has the opportunity to embrace a new transportation paradigm, one based not on personal ownership of one's mobility, but on what is called Mobility as a Service, or MaaS. MaaS allows us to move from a system in which "I own my transportation" to one in which "I access my transportation from a menu of available options." In its narrowest definition, Mobility as a Service describes a shift away from personally owned modes of transportation and toward mobility solutions that are consumed as a service on demand.

Photo courtesy of MaaS Global

Already, major companies as diverse as automakers, ride-sourcing enterprises, and entertainment companies have begun to invest in on-demand mobility services in the United States and around the world. Toyota is working with Uber to develop a new self-driving shuttle service. Uber is also working with Volvo and Daimler on driverless cars. Waymo partnered with Lyft, presumably for the infrastructure that will allow the company to connect with customers nationwide. Waymo plans to launch commercial services using autonomous vehicles (no driver) on certain routes in Phoenix later in 2018. A public trial of its Early Rider program is already underway. BMW owns Reach Now, a carshare and

ridesource service available in Portland, Brooklyn, and Seattle, which incidentally uses the urban mobility company Ridecell's software to perform vehicle/customer matching and payment processing.

Urban mobility companies, such as Moovel, offer services more aligned with a somewhat fuller definition of MaaS, where various forms of transportation services are integrated into a single mobility platform. They offer the traveling public app-based trip-planners and integrated transit, bikeshare, and carshare payment systems. Real-time information and frictionless payment systems result in seamless transfers between modes and providers. They can dynamically determine stop locations for ***microtransit*** (information-technology (IT)-enabled private multipassenger transportation services) and other on-demand vehicles based on customer locations and can route vehicles to minimize delay based on current traffic. Some urban mobility companies offer consumers subscription services. For example, the Whim app, being rolled out in several European cities by the company MaaS Global, allows users to subscribe through their smartphones to a single package of transportation services tailored to their individual needs and preferences, enabling them to use buses, trains, bikesharing schemes, private cars, and so forth, to fulfill their daily mobility needs. Users purchase their preferred combination of services on a monthly basis, or they may pay as they go, even adding services a la cart in real time. The subscription-based method gives users access to unlimited rides on public transportation and a specified amount of Whim points that can be spent on various other modes, such as car rentals, taxis, bikeshare, and so on. Users can link Whim to their electronic calendars, enabling them to plan trips in advance and save user preferences.

Photo courtesy of MaaS Global

> Ultimately, the public is best served through a coherent, coordinated network of numerous providers.

Both sets of private-sector players (on-demand transportation providers and urban mobility software companies) are developing their applications in an intensely competitive, winner-take-all, rapidly changing economic environment. The aim is to build consumer loyalty and market share.[11] These companies must answer to shareholders and investors and, at least eventually, ensure their mobility services turn a profit. Furthermore, population density of the area being served is a key factor in the viability of on-demand services. As such, there are fewer offerings in suburban and rural communities—areas of the country in greatest need of transportation alternatives to driving. Given these market dynamics, it is highly unlikely that the private sector alone can ensure a more inclusive transportation system.

11 James Arbib and Tony Seba, "Rethinking Transportation 2020-2030: The Disruption of Transportation and the Collapse of the Internal-Combustion Vehicle and Oil Industries," RethinkX Sector Disruption Report, May 2017.

03

A Future with Universal Mobility as a Service

Universal Mobility as a Service, the vision presented in this paper, expands on these basic industry concepts of MaaS to ensure that all users' needs would be met. This can be done by making sure that all forms of available transportation are offered to customers through the MaaS framework, including the full integration of ***specialized transportation*** and by applying the principles of *universal* design to all facets of the system.

While Universal MaaS–enabling technology has been developed, it has yet to be fully deployed. The technology would allow MaaS customers to identify *all* available transportation options, evaluate their cost in terms of both dollars and time, schedule a ride, monitor progress, and pay regardless of the number of transfers and independent providers used—all through a single platform that can be accessed via mobile devices, desktop computers, and a call center. The platform would show customers their fixed-route and ***demand responsive public transportation*** options. ***On-demand transportation***, traditionally limited in the United States to those who own their own vehicle, would now include microtransit, ridesourcing, ***ridesharing***, carsharing, and bikesharing. Universal MaaS's integration of on-demand transportation offers tremendous opportunity to improve specialized transportation in the United States. The platform could even integrate volunteer transportation services.

The primary difference between Universal MaaS and the services of today's urban mobility systems lies in the full integration of specialized transportation and application of universal design to all facets of the system. While services tailored to the needs of particular populations would be available, they would be part of a single, coordinated system that as a whole meets the needs of everyone in the community, regardless of income, geographic location, race/ethnicity, disability, or age. Such a paradigm, if implemented properly, could reduce or eliminate the inherent inequities of our current transportation system, where nondrivers go underserved.

The public sector needs to play a proactive role to ensure that this current opportunity results in vastly expanded mobility and improved community environments. This can be done by putting in place policies that support Universal MaaS within a shared-use transportation ecosystem. ***Shared-use mobility*** refers to transportation services that are shared among users. ***Public transportation*** is the backbone of shared-use mobility, but shared uses also include taxis and limos, bikesharing, carsharing, ridesharing (carpooling, vanpooling), ridesourcing (especially when it involves ride-splitting, e.g., Lyft Line and Uber Pool), scooter sharing, shuttle services, and neighborhood jitneys.

> The disruptive forces within the transportation sector can be harnessed to realize a convenient and equitable transportation system only if they are integrated within a shared-use mobility ecosystem.

While Universal MaaS evolves, some portion of the traveling public would continue to drive personal vehicles for the bulk of their trips, and the system would accommodate them. Yet, as shown in polls revealing millennials' preferences for transportation alternatives beyond the automobile, the preference for travel in personal vehicles may be changing, and the sys-

Car companies such as Ford are investing in mobility services, including microtransit and bikeshare. Photo courtesy of Ford.

tem could change accordingly.[12,13,14] Personal transportation would remain an option, but the system would be better configured to support shared-use mobility. And certainly, the policy and incentive environment of Universal MaaS would not result in personal vehicles being the only truly viable form of travel as is the case today in much of the country.

A core benefit of Universal MaaS is that it could make all kinds of transportation services more convenient and appealing—stimulating a shift in mode choice among consumers. The degree to which this happens will depend on America's investment in public transportation and other shared-ride solutions, and the extent to which all entities come together to coordinate their services.

> A core benefit of Universal MaaS is that it can make all kinds of transportation services more convenient and appealing—stimulating a shift in travel choice among consumers.

This coordination would allow consumers to identify through an app the transportation options available to them for a particular trip and the cost (in terms of both time and money) of those various options. Users could quickly see their fixed-route public transportation options as well as their on-demand options. They could call a private vehicle through a ridesourcing company such as Lyft or Uber or see availability at the nearest parking or bikeshare location. They could schedule and pay for a demand responsive bus and request that the one sent be wheelchair accessible. They could use multiple modes and providers to arrive at a destination; however, the full trip could be reserved and paid for within the app. A fully implemented Universal MaaS system would rely on intelligent transportation systems to provide up-to-the-minute traffic conditions or service delay information, along with user options to respond to changes in travel conditions. While US cities would likely be early adopters of Universal MaaS, the concept is applicable to rural areas as well (see below). When effectively implemented, urban, suburban, and rural communities could be knitted together by interconnected and affordable transportation options.

> Mobility as a Service promises to create a system in which consumers of transportation may access their transportation in the most seamless way possible

Within a fully implemented Universal MaaS system—where shared-use mobility is convenient and encouraged—traffic congestion, the inefficient use of land for parking, and air and noise pollution could be substantially reduced, as policy makers effectively price and incentivize shared-mobility solutions. Those who choose to travel by foot or bike could be able to do so safely on an inviting network of streets, sidewalks, and trails.

Either human-driven or driverless vehicles could be used within a Universal MaaS system; however, the National Highway Traffic Safety Administration and many other researchers argue that driverless vehicle technology could profoundly reduce the toll of traffic fatalities and injuries on human life and our economy.

Many Americans, fatigued by transportation challenges, are ready for change. Several trends expose our current transportation system to disruption and increase the viability of MaaS.

- **Demographic change.** Millennials are fueling a new transportation paradigm with their love of apps, preference for convenience and spontaneity, comfort with the sharing economy, and expectation of connectivity anywhere at any time. Urbanization and the aging of society also increase the demand for transportation alternatives to driving.
- **Communications technology.** The near ubiquity of smartphones, global positioning systems, Wi-Fi, and cloud-based communications and data storage provide a strong foundation for multientity coordination and customer communications.
- **New service models.** Ridesourcing (e.g., on Lyft or Uber) has already mainstreamed on-demand transportation.

12 Terra Curtis and Josh Karlin-Resnick, *Autonomous Vehicles and the Future of Parking*, Nelson Nygaard and Perkins + Will, Fall 2016, http://nelsonnygaard.com/wp-content/uploads/2017/04/AutoVeh_FutureParking_FINAL.pdf.

13 Erika Interrante, *The Next Generation of Travel: Research, Analysis and Scenario Development* (Federal Highway Administration Office of Policy Transportation Studies, 2014), https://www.fhwa.dot.gov/policy/otps/nextgen_finalreport.cfm.

14 Ismail Zohdy, Nathen Huang, Nathan Keegan, Josh Lukens, "Impacts of Millennial Student Loan Debt on Transportation Choices," Federal Highway Administration Office of Policy, September 2016, https://www.fhwa.dot.gov/policy/otps/millennial_travel_choices.pdf.

» **Rapid development of automated vehicle technologies.** Driverless vehicles will change the economics of transportation. Industry profit is currently derived through the sale of vehicles to individual consumers. In the future it is likely to be replaced by bundling a variety of services within the travel environment, such as a ride, on-board entertainment, and ***real-time*** traffic and weather.[15] Even insurance might be offered based on the modes chosen for a particular trip rather than tied to a personal vehicle. Data collected during the trip, about the trip, and consequently about the rider, could offer new revenue opportunities.

To be sure, signs of these trends have already emerged. Already, most traditional car companies and technology companies developing autonomous vehicle technology have invested in one or more aspects of Mobility as a Service, at least in its most basic form. For example, GM's $500 million investment in Lyft and its acquisition of Maven and Ridescout, Daimler's investments in Moovel and Car2Go, and Ford's creation of Ford Smart Mobility and purchase of TransLoc, all demonstrate that ***original equipment manufacturers (OEMs)*** see value shifting from the physical vehicle to MaaS.[16,17,18] In his CES 2018 keynote, Ford CEO Jim Hackett focused entirely on his company's vision of the future of transportation, highlighting how smart infrastructure and autonomous vehicles together might transform the way we move about our urban environments.[19] Deloitte Consulting, in its series "The Future of Mobility," advises companies and governments that "the future mobility ecosystem's various elements are coalescing to realize that dream [MaaS] sooner than expected, which means that incumbents and disruptors need to move at top speed to get on board."[20]

Emerging technologies and past efforts at customer information, human services transportation coordination, ***mobility management,*** and multimodal infrastructure design offer a foundation on which to build Universal MaaS as outlined in this paper, and thus take MaaS beyond current industry models to realize a framework that serves everyone. Disruptive forces within the transportation sector enable Universal MaaS to become a reality. But it won't happen by chance. To take advantage of the window of opportunity that emerging disruptive technology offers, and to avoid potentially negative impacts of inevitable change, diverse players from both the public and private sectors need to take collaborative action. Universal Mobility as a Service is the framework to make that happen.

15 GM predicts that it can raise its profit margin from 7.5 percent today on the private sale of a $30,000 vehicle to 30 percent when its driverless vehicle is part of a GM-owned fleet operating 24 hours a day, 7 days a week. Jeffrey Mervis, "Are We Going too Fast on Driverless Cars?," Science, December 14, 2017, http://www.sciencemag.org/news/2017/12/are-we-going-too-fast-driverless-cars.

16 https://techcrunch.com/2018/01/25/ford-acquires-autonomic-and-transloc-as-it-evolves-its-mobility-business/.

17 Caitlin Huston, "Why General Motors Invested in Lyft," MarketWatch, January 4, 2016, https://www.marketwatch.com/story/why-general-motors-invested-in-lyft-2016-01-04.

18 Doug Newcomb, "How Daimler Is Tying Together Its Diverse Mobility Investments," Forbes, May 30, 2018, https://www.forbes.com/sites/dougnewcomb/2018/05/30/how-daimler-is-tying-together-its-diverse-mobility-investments/#4977483e3215.

19 https://techcrunch.com/2018/01/25/ford-acquires-autonomic-and-transloc-as-it-evolves-its-mobility-business/. CES was formerly known as the International Consumer Electronics Show.

20 Scott Corwin, Nick Jameson, Derek M. Pankratz, and Philipp Willigmann, The Future of Mobility: What's Next? Tomorrow's Mobility Ecosystem—And How to Succeed in It (Deloitte University Press, 2016), https://dupress.deloitte.com/dup-us-en/focus/future-of-mobility/roadmap-for-future-of-urban-mobility.html.

03

Universal MaaS and Urban Transportation

The future of transportation in our cities lies in our ability to offer consumers mobility options and create transportation networks that foster vibrant local economies and livable neighborhoods.

Urban America has already embraced new ways of getting around, while at the same time supporting traditional public transportation. Solo commuting has been on the decline in most major metro areas.[21] For example, in the Washington, DC, region, the share of drivers getting to work on their own declined 10 percentage points between 2004 and 2016, with single-occupancy vehicle travel comprising just 61 percent of commute trips,[22] compared with 77 percent for the nation as a

21 Angie Schmitt, "Where Car Commuting Is Shrinking, and Where It's Not," Streetsblog USA, September 16, 2016, http://usa.streetsblog.org/2016/09/16/where-car-commuting-is-shrinking-and-where-its-not.

22 Commuter Connections, "State of the Commute Survey 2016," Technical Survey Report, Metropolitan Washington Council of Governments, June 30, 2016.

whole.[23] Downtown Seattle added 45,000 jobs between 2010 and 2016, and captured 95 percent of the net commute trips with public transportation, biking, walking, telecommuting, or true *rideshare* (*carpool* and *vanpool*). Only 30 percent of commute trips to downtown Seattle are now made by people driving alone to work.[24] According to the Shared Use Mobility Center, in 2017, ridesource companies were operating in 300 cities in North America. Consumers could find carshare service in 400 cities, and bikeshare systems in 120 cities. Moreover, voters have voiced their support for public transportation through numerous local funding referendums.[25]

Fixed-route and on-demand public transportation would form the backbone of the Universal MaaS transportation system of the future. In fact, the success of every MaaS player is dependent on the nation having a robust public transportation system in communities of all sizes. Before Americans forego their personal vehicles, they must be confident that convenient and affordable transportation options are available. Public transportation offers the most efficient and affordable means of moving the greatest numbers of people in our cities. Privately provided transportation options should complement, rather than compete with or replace, public transportation service. Urban public transportation systems are already innovating and preparing for a new era of public transportation service. Several small city and suburban bus providers have recently reexamined their route structures to create high-frequency routes (e.g., every 10 minutes), sometimes with fewer stops, to whisk commuters to job destinations during rush hour. Los Angeles will be the second city to test microtransit—private, multipassenger on-demand transportation services using dynamically generated routes (e.g., Chariot and Via).

Without a doubt, innovations in smartphone-based trip-planning apps have already greatly improved access to quality transit information, made possible by the widespread adoption of the General Transit Feed Specification (GTFS). The GTFS provides a national platform for transit agencies to upload their route and schedule information, which can then be used by third-party app developers. The GTFS-Real Time allows trip-planning apps to connect directly with ***real-time*** bus operations to inform customers of the actual minutes and miles a particular bus is from that customer's particular stop, based not solely on the schedule, but on actual operating conditions and bus movement along a route. Furthermore, private industry is making inroads on algorithms that provide an even better estimation of arrival time.

Joseph Barr, director of traffic, parking, and transportation for the city of Cambridge, Massachusetts, underscores this shift in consumer demand: "Twelve years ago, the idea that you could find out on your phone when your bus was going to arrive was mostly a fantasy; six years ago it was an interesting novelty offered by more advanced public transit agencies. These days, if you can't tell me precisely when my bus is going to arrive then you might as well not bother pulling it out of the garage in the morning."[26]

> "Twelve years ago, the idea that you could find out on your phone when your bus was going to arrive was mostly a fantasy … These days, if you can't tell me precisely when my bus is going to arrive then you might as well not bother pulling it out of the garage in the morning,"
>
> Joseph Barr, Director of Traffic, Parking, and Transportation for the City of Cambridge, Massachusetts

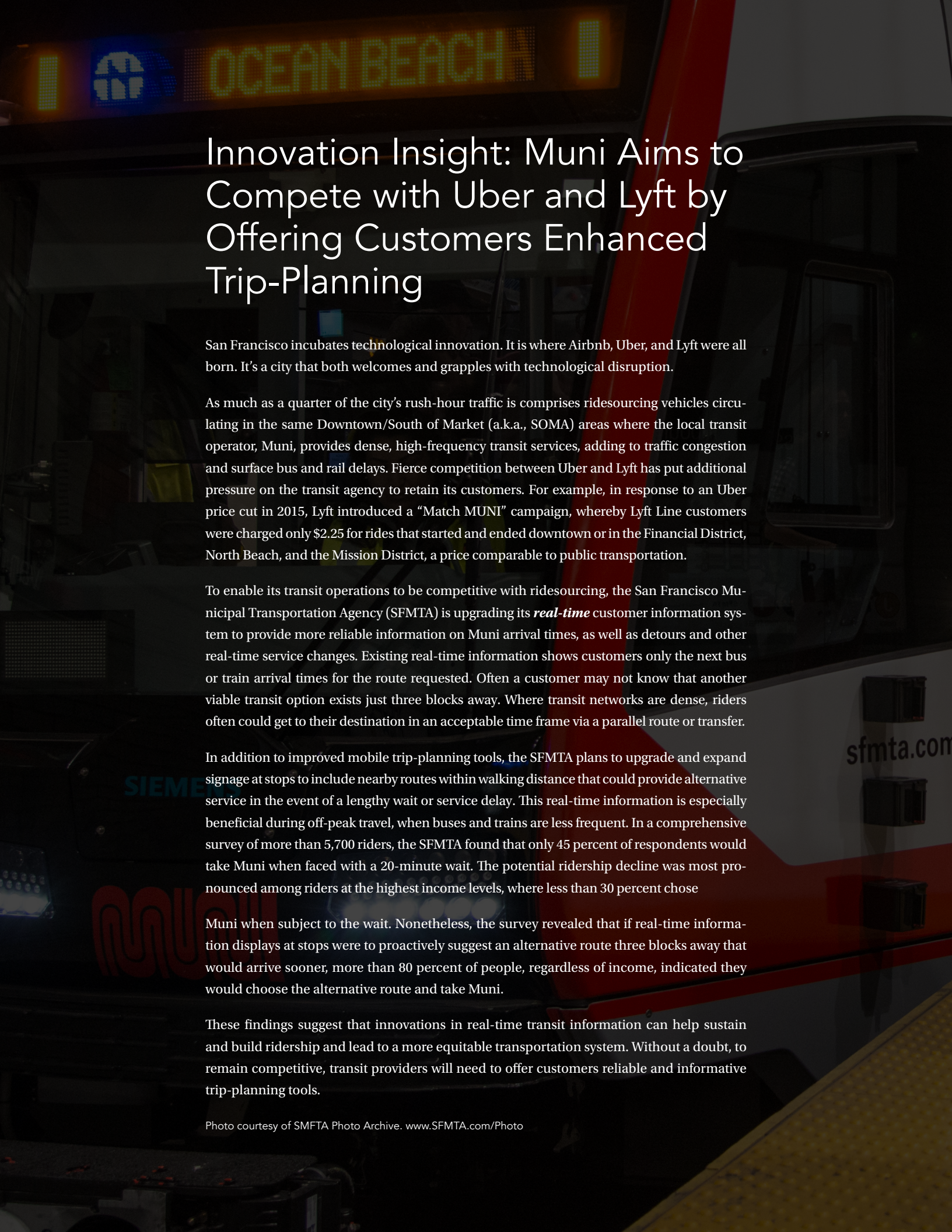
Thus, with such enabling technologies and service orientation, public transportation stands poised to not only continue in its important role but to serve as the backbone of Universal MaaS and a new transportation era.

23 US Census Bureau, 2015 American Community Survey 1-Year Estimates, https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_15_1YR_S0801&prodType=table.

24 EMC Research, "Commute Seattle Mode Split Survey Results," 2017, https://commuteseattle.com/modesplit/.

25 Recognizing the value public transportation brings to their lives and communities, US urbanites have voted to fund public transportation in 71 percent of local/regional referenda in the past 16 years (2000–2016). In 2016 alone, voters approved 54 out of 77 measures generating at least an estimated $170 billion for transit Center for Transportation Excellence, http://www.cfte.org/.

26 Joseph Barr, "Transportation Communications: No One Told Me It Would Be This Hard," Meeting of the Minds, August 17, 2017, http://meetingofthemminds.org/transportation-communications-no-one-told-hard-22315?utm_source=Meeting+of+the+Minds+Newsletter+List&utm_campaign=09dfa28dfa-RSS_EMAIL_CAMPAIGN&utm_medium=email&utm_term=0_cdb70a5ce7-09dfa28dfa-57905337&mc_cid=09dfa28dfa&mc_eid=574355608b.



Innovation Insight: Muni Aims to Compete with Uber and Lyft by Offering Customers Enhanced Trip-Planning

San Francisco incubates technological innovation. It is where Airbnb, Uber, and Lyft were all born. It's a city that both welcomes and grapples with technological disruption.

As much as a quarter of the city's rush-hour traffic is comprises ridesourcing vehicles circulating in the same Downtown/South of Market (a.k.a., SOMA) areas where the local transit operator, Muni, provides dense, high-frequency transit services, adding to traffic congestion and surface bus and rail delays. Fierce competition between Uber and Lyft has put additional pressure on the transit agency to retain its customers. For example, in response to an Uber price cut in 2015, Lyft introduced a "Match MUNI" campaign, whereby Lyft Line customers were charged only $2.25 for rides that started and ended downtown or in the Financial District, North Beach, and the Mission District, a price comparable to public transportation.

To enable its transit operations to be competitive with ridesourcing, the San Francisco Municipal Transportation Agency (SFMTA) is upgrading its ***real-time*** customer information system to provide more reliable information on Muni arrival times, as well as detours and other real-time service changes. Existing real-time information shows customers only the next bus or train arrival times for the route requested. Often a customer may not know that another viable transit option exists just three blocks away. Where transit networks are dense, riders often could get to their destination in an acceptable time frame via a parallel route or transfer.

In addition to improved mobile trip-planning tools, the SFMTA plans to upgrade and expand signage at stops to include nearby routes within walking distance that could provide alternative service in the event of a lengthy wait or service delay. This real-time information is especially beneficial during off-peak travel, when buses and trains are less frequent. In a comprehensive survey of more than 5,700 riders, the SFMTA found that only 45 percent of respondents would take Muni when faced with a 20-minute wait. The potential ridership decline was most pronounced among riders at the highest income levels, where less than 30 percent chose

Muni when subject to the wait. Nonetheless, the survey revealed that if real-time information displays at stops were to proactively suggest an alternative route three blocks away that would arrive sooner, more than 80 percent of people, regardless of income, indicated they would choose the alternative route and take Muni.

These findings suggest that innovations in real-time transit information can help sustain and build ridership and lead to a more equitable transportation system. Without a doubt, to remain competitive, transit providers will need to offer customers reliable and informative trip-planning tools.

Photo courtesy of SMFTA Photo Archive. www.SFMTA.com/Photo

HealthTran Trip Provided in Partnership with Feonix - Mobility Rising.
Photo courtesy of Feonix Mobility Rising.

03

Universal MaaS and Rural and Intercity Transportation

The potential benefits of Universal MaaS extend beyond urban areas. Rural public transportation in America today is limited. Service may span only a few hours of the day, buses may come only once an hour, or customers may need to reserve a ride 24–48 hours in advance. Yet, a vision that includes being able to lead a reasonably connected life without owning a car is attainable in rural America.

Despite the inadequacy of service today, our nation does have a solid foundation in rural public transportation services that can, with sufficient investment, enable Universal MaaS to reach rural areas. More than 80 percent of counties nationwide have rural transit service.[27] Many potential riders are unaware of the service that exists in their community, or they are unaware that it serves everyone. Extremely limited budgets have required that rural transit agencies focus on tailoring their services for clients of the human service agencies that contribute funding. The lack of resources has meant that most rural systems cannot provide a service level amenable to the general public, or even marketing dollars to let them know of the service that does exist.

> Our nation has a solid foundation in rural public transportation services that can, with sufficient investment, enable MaaS to reach rural areas. More than 80 percent of counties nationwide have rural transit service.

Universal MaaS, while initially a concept for urban areas, could result in expanded mobility in small towns and rural areas as well, although the shift to this new paradigm will happen at a slower pace than in cities. Public bus service will play an important role, but alternative shared-ride solutions may offer a competitively priced advantage over traditional public transportation in certain circumstances. Transportation policy should support the best mix of transportation options that facilitate broad mobility.

Trends suggest that rural populations are eager to embrace the shifting transportation landscape. Just as urbanites have responded positively to improvements in their transit service, so too have rural residents. Between 2007 and 2015, ridership on rural public transportation services increased 8 percent, despite declining population.[28]

With sufficient investment, rural transit systems can provide a level of service that attracts riders from the general public. To do so, they will need funding to expand service hours that cover the core travel times of the work day and they will want to connect to regional employment and transportation hubs, such as intercity bus and rail stations, and airports with commercial flights.

In some ways, rural transit providers are well positioned for the transition to on-demand services, given the dominance of demand responsive transportation service tailored to customer needs in rural areas today. Rural transit providers will need to stay abreast of technology solutions that offer improved coordination capabilities and look for ways to stay nimble as the operating environment changes. In the near term, they should upload their fixed-route data into the GTFS and their demand responsive service information into the GTFS-Flex (see sidebar on p. 24). This will allow both their fixed-route and demand responsive services to become known to consumers through Google Transit and other trip-planning apps. Federal Transit Administration and state Department of Transportation transit program managers should quickly identify outdated policies and regulations that could inhibit innovation. They, along with local agencies, should require both public and private operators of demand responsive services to use the forthcoming transactional data specification to foster better coordination of services (see section on Universal MaaS and Specialized Transportation).

Alternative shared-ride solutions may offer a competitively priced advantage over traditional public transportation in certain circumstances.

Communities can also look to private providers to help build Universal MaaS. For example, The non-profit Feonix Mobility Rising is helping HealthTran, a program of the Missouri Rural Health Association, and two Federally Qualified Health Centers, expand its reach by coordinating volunteer drivers, public transit and local taxi services via the QRyde platform. Feonix will soon bring its mobility services to communities in rural Nebraska, South Carolina, Texas, and Wisconsin. ITN*America* intends to bring a variation (ITN*Country*) of its award-winning volunteer transportation format to rural communities in the near future. Public receptivity to spontaneous carpooling services is growing, as app-based technology facilitates the ease of ride matching.

27 Jeremy Mattson, "Table 14," in Rural Transit Fact Book 2017 (Upper Great Plains Transportation Institute, Small Urban and Rural Transit Center, North Dakota State University, October 2017), https://www.surtc.org/transitfactbook/downloads/2017-rural-transit-fact-book.pdf.

28 Todd Litman, "Public Transit's Impact on Rural and Small Towns: A Vital Mobility Link," Victoria Transportation Institute for the American Public Transportation Association, October 2017.

Innovation Highlight: VTrans Implements the GTFS-Flex

If there is a bus but no one knows about it, is the bus really serving the community?

In an effort to build public awareness of the state's transit services, the Vermont Agency for Transportation (VTrans) is the first in the nation to test the GTFS-Flex. Through a new trip-planning app, customers will soon be able to enter their desired origin and destination and access information about demand responsive services, including provider contact information, geographic coverage area, hours of service, and type of service. Once the state's data have been uploaded, other trip-planning apps, such as Google Transit, could also consume the service information into their systems.

Without the GTFS-Flex potential customers cannot simply pull out their smartphone and figure out how to travel by public transportation where those services do not follow a set route or schedule. This limitation affects many rural residents and both rural and urban residents who rely on more specialized transit services. The GTFS-Flex allows the "discovery" of available transit services for a given trip; however, it does not enable the customer to book and schedule a trip on the bus. It simply provides that customer with the information necessary to complete the transaction. Nonetheless, this is an important step in building a Universal MaaS system.

Demand responsive transit services take several forms, including:

- Traditional dial-a-ride
- Flag stop service where riders can request to board or alight at any point along a route
- Route deviation where vehicles deviate from their scheduled route to pick up or drop off a customer within an approved zone
- Point deviation where vehicles serve respond to customer requests for pickups or drop-offs at a limited number of stops within a specified zone.

Each form of demand responsive service is visible to potential customers through the GTFS-Flex.

Vermont has public transportation service in every county, much of it in the form of demand responsive service designed to serve more rural markets. Implementation of the GTFS-Flex is a positive step in enabling residents in rural areas to travel by transit across county boundaries and even connect to private, interstate bus and rail to reach distant cities up and down the Eastern Seaboard. Trip planning will soon be as easy as whipping out a smartphone.

Photo courtesy of Vermont Agency for Transportation.

Intercity Travel

Intercity travel is an important, but often unmentioned, element of Universal MaaS. The services provided by Amtrak, Greyhound, rental car companies, private airport shuttle operators, and others can be integrated into a national Universal MaaS platform so that travelers can quickly find their options for getting from point A to point B, even for destinations they have little, or no, familiarity with.

In fact, such shifts are already happening. Providers have been slowly building a foundation for this coordination. Amtrak and Greyhound have linked their ticketing services for some routes, allowing customer transfers from one provider to another on a single ticket. The Intercity bus company, Jefferson Lines, now uploads its route and schedule data to the GTFS, making about 50 intercity routes in 14 states immediately known to potential customers via Google Transit. Greyhound is following suit.

Photo by AARP.

03

Universal MaaS and Specialized Transportation

The transportation disruption also stands to improve service quality and efficiencies in specialized transportation. To date, MaaS developers have not typically focused on travelers with special needs, but if carefully designed, MaaS could vastly improve transportation for those who now rely on family and institutions for their transportation.

Many people with disabilities and other individuals with mobility limitations, regardless of age, need specialized transportation—such as door-to-door or door-through-door paratransit services, which have been traditionally provided on request by van, small bus, or taxi. Various human services providers arrange this form of transportation for their clients. Some may provide the service directly. Others may contract service through a public or private paratransit provider. For example, Area Agencies on Aging may arrange van service to senior centers or adult day centers. Vocational rehabilitation agencies may provide transportation to young adults with disabilities between home and a work site. A nonprofit may offer transportation to medical appointments through a network of volunteer drivers. Each entity may draw on funding from different federal agencies and have different eligibility criteria and service parameters. In many communities these services may be overlaid with local fixed-route and Americans with Disability Act (ADA) paratransit services. Often, service is redundant and inefficient, and navigating the system is challenging for consumers. Efforts to coordinate services, even after several decades, arguably have fallen short.

Since the creation of the federal Coordinating Council on Access and Mobility in 2004, federal agencies have worked with state and local transportation partners to improve the coordination of these services. One of the stumbling blocks has been the challenge of getting the various ride scheduling and dispatch systems to communicate with one another. Coordination of demand responsive transportation is more challenging than simply creating an open data specification that providers can use to upload route and schedule data (e.g., the GTFS system) as a paratransit vehicle's route changes dynamically with incoming trip requests. Personal data that include riders'

Photo by AARP.

Innovation Highlight: Travel Washington

The private sector has provided intercity bus service in the United States for generations. But changing market conditions no longer allow intercity bus companies to profitably serve many of our nation's small towns. As a result, between 2005 and 2010 alone, 8.4 million rural residents lost access to scheduled intercity bus transportation. Private bus companies now serve 750 fewer intercity bus depots nationwide.[30]

To address this problem in its state, the Washington State Department of Transportation introduced Travel Washington, an innovative public–private partnership that uses the investment that Greyhound makes in the state to count toward the state/local match requirements for federal intercity bus funding. With this funding, the state introduced four new intercity bus routes, serving more than 50,000 passengers each year. The routes link people living in remote communities to cities, regional health care centers, local and international airports, intercity bus and rail stations, and tourist destinations—often on a single ticket.

Originally this funding arrangement was allowed as a pilot program only in the state of Washington. Congress has now opened this funding opportunity to all states, 29 of which now have a program in place.

For more information on Travel Washington, view this AARP video and publication.

30 Bureau of Transportation Statistics, "The U.S. Rural Population and Scheduled Intercity Transportation in 2010: A Five-Year Decline in Transportation Access," US Department of Transportation, Research and Innovative Technology Administration, Washington, DC, February 2011.

home and destination addresses must be protected, as must the proprietary algorithms of the various software companies.

Nevertheless, progress is tangible and nearly ripe to yield some results in the United States. An applied research project through the National Academies of Sciences (NAS) Transit Cooperative Research Board is underway to address this specific hurdle.[31] When the study wraps up in late 2018, the research team will release technical specifications for the sharing of what is termed "transactional data." This is the portion of data that needs to be shared between the ride dispatcher and potential trip providers in order to enable the ride to be scheduled.

While these data specifications aim to address problems in coordinating existing demand responsive transportation services, they play another role that may end up being equally impactful. They will lay a foundation for future on-demand mobility for customers needing more specialized services. Today, these customers may have access to, or be aware of, only a single type of service and provider. In the transportation ecosystem of the future, many of these individuals could tap into a wider selection of ways to get around their community. For instance, a person with dementia might opt to ridesource or use public transportation when traveling with a caregiver but rely on the adult day center shuttle bus when traveling alone.

A Universal MaaS system, where specialized transportation services are integrated into a single platform along with other means of shared-use mobility services, could be smart enough to apply the appropriate subsidy for each unique human services transportation client and trip request, while protecting the privacy of the individual. For example, a qualifying Medicaid customer's medical travel would be charged to the state or other appropriate entity such as the Medicaid nonemergency medical transportation (NEMT) broker. His or her nonmedical travel would be charged to a personal account or other subsidizing entity as appropriate. Gone, therefore, would be the days when that customer would have to go directly home rather than make a convenient stop-off at the grocery store because Medicaid only covers the medical portion of his or her trip.

Beyond convenient cost allocation, MaaS could be enhanced by the addition of mobility management, which lends a human dimension to a system that is otherwise primarily tech based. Mobility managers could provide direct assistance for complicated trip planning or even travel training—supplementary services to readily available one-click, one-call information centers.

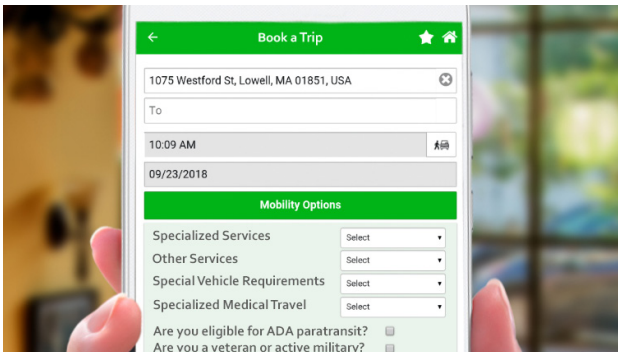


Image courtesy of QRyde.

Thus, Universal MaaS could bring together multiple transportation options in a coordinated system that enables customers to plan trips, schedule rides, and pay for service with the click of a button. As on-demand transportation options proliferate, existing and new providers of specialized services will need to ensure that on-demand transportation is as readily available to those with special needs as it is for the general public.

To become part of a Universal MaaS platform, specialized transportation services—both demand responsive and on-demand—would need to adopt the common transactional data specification. Data systems need to be interoperable so that a viable Universal Mobility as a Service system can be built. Without interoperability, a seamless one-stop platform where customers can shop, schedule, ride, and pay for their selection of services will not be realized. A commitment to institutional cooperation on the part of all players is needed. In fact, their success in this space is dependent on realizing Universal MaaS. While competition among them is both inevitable and desirable, all players benefit from having interoperable data-sharing platforms and strong public transportation systems. It is yet to be seen whether profitability demands on companies in this space will enable them to share their data more openly and participate as members of a larger network of transportation providers. The public sector will need to play a strong role in making this data sharing and interoperability happen, and to protect consumer privacy when it does. To date, neither Lyft nor Uber has engaged in the development of the transactional data specification despite numerous invitations from the NAS study team to do so. This raises the concern that each company may try and go it alone, and even try and displace publicly provided demand responsive services, rather than work with multiple public and private players to build a true Universal MaaS system.

31 "G-16 Research Project: Development of Transactional Data Specifications for Demand Responsive Transportation, Accessed 10/30/2017.



Photos courtesy of Sydtrafik and Nordjyllands Trafikselskab

Innovation Insight: FlexDanmark

In Denmark, if you have trouble using regular bus services because of age or disability, getting around your community, and even country, doesn't pose the challenges that many travelers face in the United States. Multiple transportation options tailored to individual needs can be accessed and paid for through a single system.

Denmark is a model of truly coordinated demand responsive transportation services. The country has five call centers integrated with a central nationwide dispatch system, which assigns each trip request to a transportation provider that then sends an appropriate vehicle to the customer's door. More than 550 different public and private transportation providers are integrated into this single system, which serves both urban and rural customers throughout Denmark. Hospitals, medical offices, and human service agencies easily connect their clients with the FlexDanmark portal. Regular citizens can obtain transportation to a medical appointment at a more affordable price than a taxi, because FlexDanmark can quickly identify another customer to share a ride with. Trips may be booked in advance or real time (on demand). In addition to scheduling and dispatching, the FlexDanmark call centers also monitor real-time traffic conditions and reroute drivers to avoid delay, helping to minimize travel time for the customer.

The sophisticated level of coordination is possible because all providers in the system adopted a common transactional data specification. Originally developed in Sweden, the SUTI (Standardiserat Utbyte av Trafik Information)[32] specification standardizes trip request data across multiple providers and platforms. A huge volume of exchangeable data is generated and managed by software applications that are SUTI-compliant, enabling as many as 20,000 trips daily to be booked and completed in Denmark. The specification has lowered the market-entry costs for new (often small) transportation business owners and has reduced the cost of providing human services transportation on average by 20 percent, and as much as 40 percent for rural trips. This cost savings is beneficial to customers who pay out of pocket for the service, as well as the human service agencies that subsidize travel.[33]

Denmark has also integrated traditional (fixed-route) public transportation services with demand responsive transportation in the most rural regions of the country, enabling customers to identify options for affordable door-to-door service in rural areas. Transfers between the fixed-route system and one of the SUTI-compliant demand responsive transportation providers can be made on a single ticket and payment.

32 http://u3545014.fsdata.se/blogg/

33 Personal communication with Niels Tvilling, consultant to the National Academies of Sciences Transit Cooperative Research Program G-16 Research Project, March 19, 2018. Research Project, March 19, 2018.

The ideal Universal Mobility as a Service platform would include the combined characteristics of urban mobility platforms such as Whim (see p.15) and FlexDanmark (see above box), where demand responsive service is coordinated among providers and then fully integrated within a MaaS platform that offers customers all other options for getting around the community, along with seamless payment systems and traveler information.

While several urban mobility companies have the technology in place to offer many of these MaaS features, the integration of demand responsive transportation is not common. A platform called Switch may be among the first to change that and offer the first true Universal Mobility as a Service Technology. The Switch app is expected to launch in the United States summer 2018.

One challenge that has arisen is that all MaaS developers are struggling to figure out a profitable business model. Public agencies, especially public transit operators, are a logical client base for MaaS, but except for the largest operators, they are not used to paying for sophisticated information tools. And all transit agencies struggle to find funding for core services. Thus, the public sector often purchases just one MaaS component, such as payment systems offered through a mobility app. Another client base for MaaS can be found in the private sector. Private, on-demand providers may purchase the ***white-label*** technology needed to run a stand-alone ridesourcing or carsharing operation, but these same clients question the value of offering their services through a common app and platform. It has proved challenging the pull them into a multiple-provider MaaS framework.[34]

> The best approach to tackling affordability challenges and protecting the interests of the public is to develop ***open-source*** platforms.
>
> Kevin Chambers, Founding Principal, Full Path Transit Technology

Kevin Chambers, a technologist with experience helping small public and nonprofit transportation providers, suggests that the best approach to tackling affordability challenges and protecting the interests of the public is to develop ***open-source*** platforms.[35] He arrived at this conclusion after years of near-fruitless effort to integrate the proprietary software systems used by different demand responsive transportation providers, a lament shared by many other providers across the country hoping to coordinate demand responsive services regionally.

RidePilot is an open-source, web-based transportation scheduling and grant-reporting system tailored to the budgets of smaller public and nonprofit specialized transportation providers. RidePilot can be linked with 1-Click, another open-source tool in a suite, to enable customers to review itinerary options before selecting and requesting a service.

Whether the system is built using proprietary software and algorithms, or completely open source, every Universal MaaS provider in it will need to adopt the common transactional data specification in order to coordinate scheduling and dispatch across multiple providers' vehicles within the system. This interoperability is essential for the creation of a truly Universal MaaS system.

34 Daleb Diehl, "The Transporter," Oregon Business, January 23, 2018, https://www.oregonbusiness.com/article/transportation/item/18172-the-transporter.

35 Comments delivered at AARP "Age-Friendly Transportation: How is Technology Changing the Way We Move" public forum, March 7, 2018, Portland, Oregon.

04

It's Not Universal MaaS without Universal Design

MaaS offers a tremendous opportunity to expand mobility options to people with disabilities and older adults who are frail. To succeed, MaaS must embrace universal design in both customer interaction and vehicle design.

The concept of *universal design*, a term often used in the context of making homes and buildings accessible to all people, is an important piece of the transportation puzzle as well. Universal design is the design of buildings, vehicles, environments, products, services, and user interfaces that are broadly accessible to people with disabilities, older people, young children, and everyone else. It is a rejection of the notion that things be designed for the "average" person, which too often results in separate facilities for people with disabilities—for example, a ramp set off to the side of a stairway or a separate paratransit bus service when an accessible fleet of public buses could serve the needs of many wheelchair users just as well. Universal design, on the other hand, provides one solution that can accommodate everyone.

Core advocates for autonomous vehicles have used the needs of older nondrivers and people with disabilities as a primary rationale for public support of the technology. Now is the time for autonomous vehicle designers to step up and lead in this area. Every player in this emerging system should become competent at truly understanding the needs of older nondrivers and people with disabilities and design MaaS delivery systems, vehicles, and customer apps with this in mind. Universal design cannot be an afterthought.

When designing services for populations with special needs, systems designers need to understand that they are designing for a wide variety of mobility needs and limitations. Employing the concepts of universal design is crucial. Too often, designers limit their task to one of overcoming barriers for people who are blind or who use wheelchairs. The traveling public is far more diverse.

04

Service Delivery for Customers with Special Needs

One of the most important design considerations when serving customers with special needs is the human dimension of service. Volunteer and paratransit drivers are often cited in the senior transportation literature as providing more than just a ride. They offer social interaction. They also commonly identify when an older adult may be declining and alert family members or social services about their concerns. Within a MaaS system, appropriate driver training is essential for those transporting older adults with special needs. Training should include instruction on how to physically assist riders up and down stairs, provide assistance walking along uneven surfaces, and help clients in and out of wheelchairs. Drivers should know how to recognize and appropriately respond to clients with tremors, Alzheimer's, Parkinson's, vision issues, hearing issues, and balance issues. Driver training is also important to ensure drivers understand their requirements under the ADA, and when and how to assist an individual in and out of a vehicle without injuring either the passenger or themselves. General sensitivity training should also be included. It is equally important to recognize that not all riders will want or need assistance.

> One of the most important design considerations when serving customers with special needs is the human dimension of service.

As driverless vehicles replace for-hire services, including taxis, ridesourcing, and buses, there will continue to be a need for personnel who can assist riders with special needs. In some cases, the best solution will be to continue to employ personnel who can continue to perform these related tasks. In other cases, a solution may be for providers of transportation services to allow care attendants to ride for free or to provide care attendants themselves. The industry might introduce levels of certified expertise ranging from laypersons trained in common systems of dementias and helping someone in and out of the vehicle to trained nurses and other health care personnel. SilverRide, currently operating in the San Francisco Bay Area but with nationwide expansion ambitions, offers all clients door-through-door assistance. In addition, riders, or caregivers scheduling a ride for a loved one, can request Accompaniment, whereby SilverRide's Driver Companions accompany the client during an appointment or activity. A third option, albeit with more limited utility for many, could be to install a virtual personal assistant in the vehicle that could interact with the client and even sense if the rider is getting anxious or otherwise alert the device to a potential problem, at which point the device could remotely connect the passenger with a care attendant.

Image courtesy of GoGoGrandparent.

Maas Needs Mobility Management

The term *mobility management* can mean different things depending on the professional frame of reference, but each conceptual definition is important to Universal MaaS. Social service–oriented professionals view mobility management as a way to bring a human dimension to MaaS. According to the National Center for Mobility Management, "Mobility management is a customer-centered approach to designing and delivering mobility services."[36] Already, numerous transit agencies, Area Agencies on Aging, and medical practices, among others, have hired mobility managers to help their clients navigate the full range of transportation services in the community, effectively matching the individual to the most appropriate service for a given trip.

In the world of transportation planning, mobility management is now defined as the essential role the public sector must play in managing the tremendous amount of choice in travel today. While human services transportation providers view the role of mobility managers as connecting older adults, people with disabilities, and low-income individuals to appropriate transportation services, transportation planners have the general population in mind when they refer to mobility management.

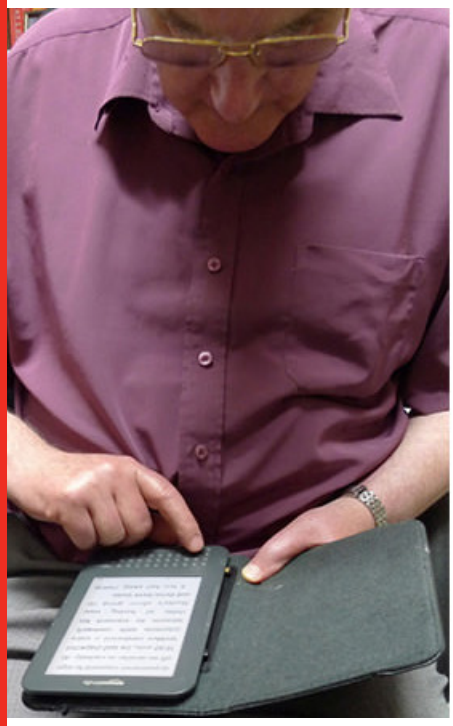
To confuse the term even more, in the world of tech, mobility management has also been described as "combining an individual's specific travel history and current circumstances with data from millions of others and information from different modes of travel across the city. Applying advanced analytics to big data, they offer users tailored, seamless options."[37]

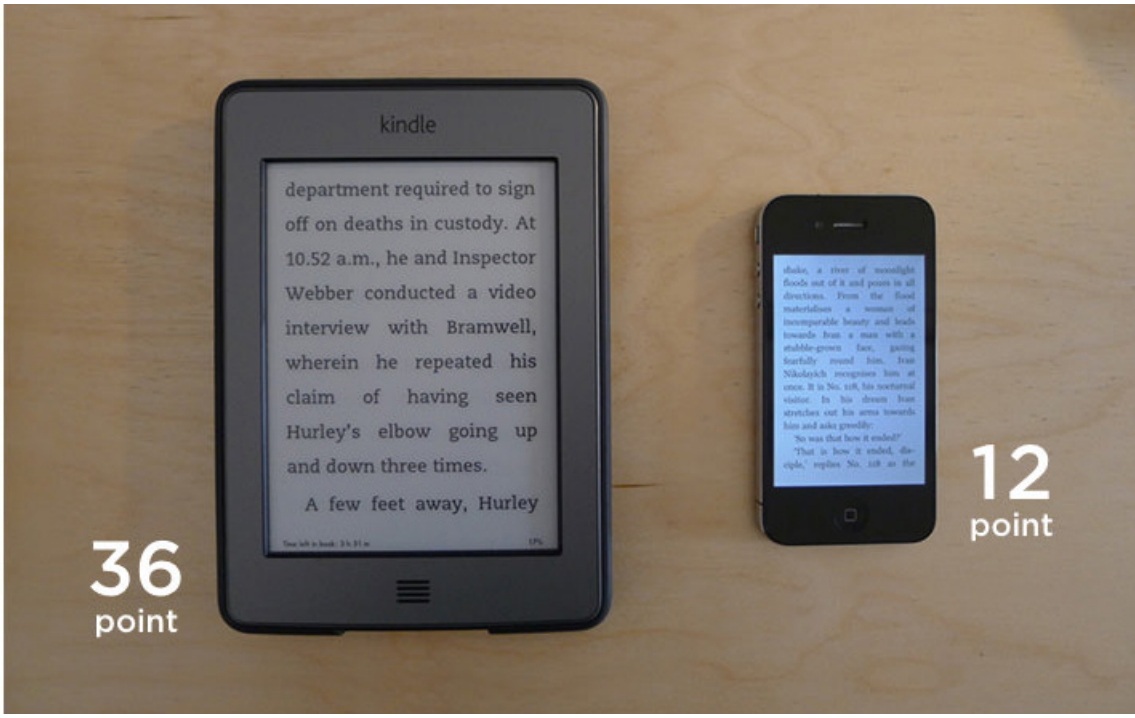
> In the new transportation ecosystem, all forms of mobility management will need to come together to offer all customers more seamless travel options.

Lyft helps senior living residents reduce isolation and increase their independence across the U.S. Photo courtesy of Lyft.

36 "Glossary of Transportation and Related Terms," National Center for Mobility Management, accessed October 30, 2017, http://nationalcenterformobilitymanagement.org/wp-content/uploads/2013/12/Glossary-of-Terms.pdf.

37 https://dupress.deloitte.com/dup-us-en/focus/future-of-mobility/roadmap-for-future-of-urban-mobility.html?id=us:2el:3dc:dup3367:awa:dup:fom:dcpromo#endnote-9





Comparison of a typical 75-year old's preferred font size with the typical font size on a smart phone. Original published in Smashing Magazine. https://www.smashingmagazine.com/2015/02/designing-digital-technology-for-the-elderly/

04

App Design for the Individual and Family Caregiver

Navigating online apps is not easy for everyone. Some people, including 54 percent of those ages 65 and older, do not have a smartphone.[38] Others lack familiarity with how to use modern technology applications. Further, a device or app's interface may not be conducive to use by those with poor eyesight or (in the case of devices) arthritic fingers.

Through universal design, some barriers could be overcome simply by designing the device and apps with greater attention to the variation in user needs (e.g., larger keyboards, selection of background and font colors with greater contrast, and improved voice recognition systems). In the meantime, some companies have addressed barriers by designing flexible customer interfaces. Lyft's partnership with GoGoGrandparent enables an older adult to schedule a trip with a phone call and loved ones to track that trip through text messaging. Both Lyft and Uber have put systems in place that allow partners (e.g., hospitals and senior independent living centers) to request rides for their customers through the Lyft or Uber platforms and enable those partners to fully or partially subsidize those trips for their clients. A Universal MaaS system would ensure that these types of tailored interfaces could be accessed through the common platform.

38 Although their use of the technology is growing, only 46 percent of Americans ages 65 and older own a smartphone, compared with 73 percent of those 50–64, 89 percent of those 30–49, and 94 percent of those 18–29. Pew Research Center, "Mobile Fact Sheet," February 5, 2018, http://www.pewinternet.org/fact-sheet/mobile/.

04

Vehicle Design

Prototype designs of driverless vehicles inspire a sense of "the future," but often forget to carry forward known universal design elements of today. This emerging transportation future invites more design leadership to ensure that driverless cars are easy for someone with advanced arthritis to get in and out of and that prototype transit shuttles and buses have ample grab bars and accessible seat designs.

Whether autonomous or not, vehicles intended to transport the traveling public must be designed with both audio and visual interfaces. People who are blind cannot interface with visual; people who are deaf cannot interface with audio. All other users benefit from redundancy.[39]

Photos of the Mercedes Benz Future Bus found on Twitter https://twitter.com/search?q=Mercedes%20%20Benz%20Future%20Bus&src=-typd"

39 National Council on Disability, https://ncd.gov/sites/default/files/NCD_AutomatedVehiclesReport_508-PDF.pdf and http://www.rudermanfoundation.org/wp-content/uploads/2017/03/Self-Driving-Cars-The-Impact-on-People-with-Disabilities_FINAL.pdf

05 Other Equity Considerations for Universal MaaS

The mobility services revolution also offers an opportunity to address the needs of lower-income travelers.

Many residents of low-income communities, often communities of color, face barriers to accessing the most touted new mobility services. Lower-income individuals may carry a smartphone but not subscribe to data services or Wi-Fi. They may lack a driver's license, bank account, or credit card through which to access app-based subscriptions. They are more likely to live in apartment complexes without access to electric vehicle charging stations. Some may be particularly concerned with the privacy of electronic payment systems and information sharing about individuals' travel patterns with law enforcement entities. They could also face language barriers. Access barriers documented by OPAL, an environmental justice advocacy group, include banking, housing type, and tech literacy, not to mention the cost of transportation itself.[40]

Potential solutions include more extensive public Wi-Fi networks, apps in multiple languages, and the retention of cash-payment options for public transit users. Alternatives to credit cards should be offered to those who wish to subscribe to transit passes, bikesharing and carsharing, and other forms of shared-use mobility. Public entities and banking institutions can partner to offer low- or no-fee bank accounts to unbanked individuals who are unable to carry a standard account balance and allow these accounts to interface with mobility payment systems. Perhaps most important, sufficient investment in public transit that serves lower-income communities is needed.

40 Kristin Eberhard, "Equity Impacts of Shared/Electric/Connected/Autonomous Vehicles," Session presentation at Urbanism Next conference, Portland, Oregon, March 6, 2018. Additional information available at http://www.opalpdx.org/.

06 Driverless Vehicles within the MaaS Framework

Waymo's fully self-driving reference vehicle, Firefly 2. Image courtesy of Waymo.

MaaS can happen with or without driverless vehicles, but as the technology changes the economics of travel, it increases the likelihood that transportation will take the form of on-demand services.

Fleets of driverless electric vehicles requiring lower maintenance, energy, finance, insurance, and replacement costs, in combination with much higher vehicle utilization rates, could mean mobility 4 to 10 times cheaper than buying a new car.[41] As a result, RethinkX, an independent think-tank that analyzes and forecasts the speed and scale of technology-driven disruption and its implications across society, suggests that 95 percent of all US passenger miles will be served by providers who will own and operate fleets of driverless electric vehicles within 10 years of widespread regulatory approval of autonomous vehicles.[42]

Others predict the status quo for the foreseeable future. Americans have demonstrated a "love affair" with the car, and car purchase decisions do not always reflect the most economical choice available, especially given that our vehicles sit parked 95 percent of the time.[43] To the American psyche, cars are "extended backpacks, lifestyle aspirations, decompression zones, status signifiers, vacation vehicles and fashion accessories," wrote Michael Barnard in *Forbes*.[44] But to accept the status quo is to accept that America's transportation system will remain inefficient and inequitable. Introducing driverless technology into the market as a vehicle feature, such as leather seats or alloy wheels, may significantly drive up car purchase prices, making them unaffordable, or requiring purchasers to incur higher car loans, to the detriment of personal savings or other wealth-generating investment. It could also create or exacerbate

41 Arbib and Seba, "Rethinking Transportation." Note: Their projection addresses Level 5 fully autonomous vehicles.

42 Many industry analysts in the United States think of MaaS as simply the replacement of personally owned vehicles with a system where passengers access transportation on demand, and not as the integration of various forms of public and private transportation services into a single mobility platform.

problems in ways the public may not expect—for example, it could tax the capacity of the existing road system by enabling owners the option of avoiding parking fees by sending the car around the block or home to be parked for free in the driveway, adding more miles to our already burdened roads.

> Autonomous vehicles could create or exacerbate problems in ways the public may not expect—for example, adding more miles to our already burdened roads.

Simply rolling out the technology through privately provided on-demand platforms, as commonly envisioned by automotive and ridesourcing companies, still may not reduce the cost of travel sufficiently for low-income Americans and it promises few benefits for people who depend on an accessible vehicle. Furthermore, there is a risk that the price of this form of on-demand service would be affordable and preferable to today's moderate- and upper-income transit users, potentially siphoning an important ridership base and resulting in less political support and funding for public transit services. Lower-income travelers would stand to lose the most from worsening transit service.

> To accept the status quo is to accept that America's transportation system will remain inefficient and inequitable.

Thus, the future of transportation is exciting yet potentially concerning, which is why Americans cannot afford to be passive. To realize the benefits of this compelling transportation future, the vast majority of driverless vehicles operating on our nation's roads will need to operate as part of a shared-ride, Universal MaaS model. As part of this *Future of Transportation* series, the author explores these issues in depth in a paper titled *Utopia or Dystopia: The Future Is Ours.*[45]

> To realize the benefits of this compelling transportation future, the vast majority of driverless vehicles operating on our nation's roads will need to operate as part of a shared-ride, Universal MaaS model.

Photo courtesy of Volvo Car Group Global Newsroom.

43 David Z. Morris, "Today's Cars Are Parked 95% of the Time," Fortune, March 13, 2016, http://fortune.com/2016/03/13/cars-parked-95-percent-of-time/.

44 "What Will Car Ownership Look Like in the Future?," Forbes, June 22, 2017, https://www.forbes.com/sites/quora/2017/06/22/what-will-car-ownership-look-like-in-the-future/#353ca3166b99.45

45 Jana Lynott, "Utopia or Dystopia: The Future is Ours," AARP Public Policy Institute, (forthcoming, Fall 2018).

07

Creating the Transportation System We Want: Building Blocks for the Road Ahead

Impending disruptive forces promise to change transportation as we know it today. It is imperative that we actively shape the transportation system we want to see rather than passively wait and see what happens.

The up-ending of the traditional transportation system provides an unprecedented opportunity to fix current shortcomings and create a coordinated, integrated, and seamless transportation system accessible to all.

To create a transportation system that works for everyone, policy makers at all levels of government should adopt the following dozen interdependent tenets to guide a new transportation policy framework. They are explained in detail in *Creating the Transportation System We Want: Building Blocks for the Road Ahead*[46], and further elucidated in other papers in the *Future of Transportation* series.

1. Embrace a Universal Mobility as a Service framework.
2. Prioritize shared-use mobility.
3. Adopt a strong commitment to equity.
4. Maximize independence.
5. Commit to universal design.
6. Support livable, sustainable communities.
7. Foster transportation system efficiency.
8. Encourage data system and platform interoperability.
9. Put in place a transparent system to measure impacts, both positive and negative.
10. Prioritize safety for all modes of travel.
11. Provide consumer protections.
12. Manage the effects of resulting economic shifts, facilitating career transitions.

The vision this paper promotes is for the future. Public opinion is hard to gauge and potential impacts uncertain. Research is needed on consumer acceptance of this concept and the wider possible effects on industry, employment, consumer protections, and society at large.

46 Jana Lynott, "Creating the Transportation System We Want: Building Blocks for the Road Ahead," AARP Public Policy Institute, (September 2018).

08 Conclusion

> "This needs to be a conversation about public policy, not technology,"
>
> Seleta Reynolds, general manager with the Los Angeles Department of Transportation

We are at the threshold of major changes in the transportation sector and we have once-in-a-lifetime opportunity to shape how the sector best serves all Americans.

With major companies investing heavily in autonomous vehicles and other revolutionizing technologies, future value will lie not only in transportation, but also, as is the case with so much of our digitally based economy, in the data and information exchanged while users are en route.

While change seems inevitable, *positive* change is not a done deal. Policy makers, city planners, and industry need to work together to ensure that these disruptive technologies realize their fullest potential to vastly increase mobility in America and respect citizens' desire for livable communities. Consistency for a new vision for transportation is critical. If US consumers are encouraged to replace their 20th century–style personal vehicles with autonomous vehicles, millions of Americans could still be left with inadequate mobility options. Even a MaaS model that is not based on Universal Mobility as a Service—where shared-use mobility is prioritized and fixed-route, on-demand, and demand responsive services are integrated—will be problematic. Consideration must be given to how low-income individuals can tap into convenient and affordable transportation options. Piecemeal services that are not integrated within a Universal MaaS framework will fail to harness the potential of emerging technology. Seleta Reynolds, general manager with the Los Angeles Department of Transportation reminds us that, "this needs to be a conversation about public policy, not technology."[47]

Universal Mobility as a Service is possible. Many industry leaders suggest that emerging technology and market environments make MaaS, at least in its narrowest form, highly likely. If implemented fully and thoughtfully, Universal Mobility as a Service can lead to a more equitable transportation system where more than 100 million nondrivers are able to more fully participate in the economic, social, and civic life of their communities.[48]

47 "Leading the Way Forward in Transportation," Plenary panel discussion at the AARP Livable Communities National Conference, Dallas, Texas, November 15, 2017.

48 AARP Public Policy Institute calculations using Highway Statistics 2016 (Federal Highway Administration), and 2016 Population Estimates (US Census Bureau).

09 Glossary of Terms

The rapidly changing transportation sector has resurfaced old and introduced new terminology. Often, writers use terms interchangeably, confusing their readers. The following glossary of terms is intended to clarify the author's word choice and is based on current industry best practices.[49] Many concepts are highly complex. Rather than presenting the most precise, technical definitions, the author has attempted to write them in layperson language.

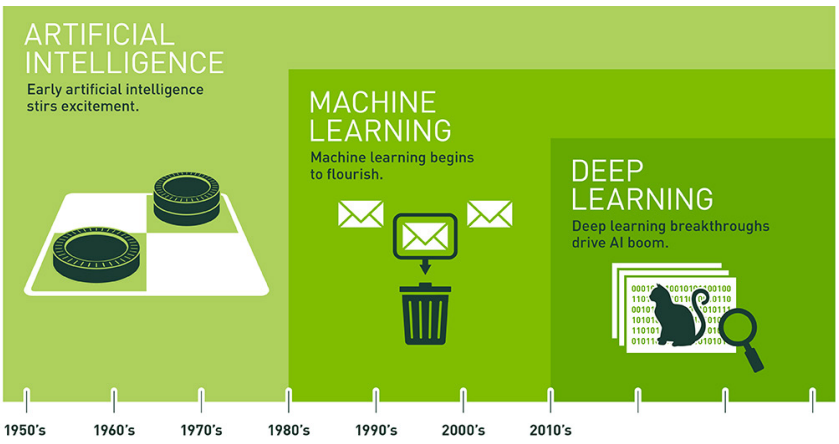
Terminology Related to Disruptive Motor Vehicle Technology

Artificial Intelligence (Evolution of)

Artificial intelligence (AI) is human intelligence exhibited by machines.

Machine learning, a subset of AI, is the practice of using algorithms to parse data, learn from them, and then make a determination or prediction about something in the world.

Deep learning is a subset of machine learning composed of algorithms that permit software to train itself to perform tasks, like speech and image recognition, by exposing multilayered "neural" networks to vast amounts of data. In the context of MaaS, it is the way in which automated driving systems can be "trained" to recognize features of the roadway environment, including people.



Since an early flush of optimism in the 1950s, smaller subsets of artificial intelligence – first machine learning, then deep learning, a subset of machine learning – have created ever larger disruptions.

The easiest way to think of the relationship among artificial intelligence, machine learning, and deep learning is to visualize them as concentric circles with AI—the idea that came first—the largest, then machine learning—which blossomed later, and finally deep learning—which is driving today's AI explosion—fitting inside both.[50]

49 This glossary of terms is adapted from definitions offered by a number of sources: National Highway Traffic Safety Administration, Shared-Use Mobility Center, Pedestrian and Bicycle Information Center, Easter Seals, National Center for Mobility Management, Insurance Institute for Highway Safety, Eno Center for Transportation, Alain Kornhauser, and Michael Copeland, among others.

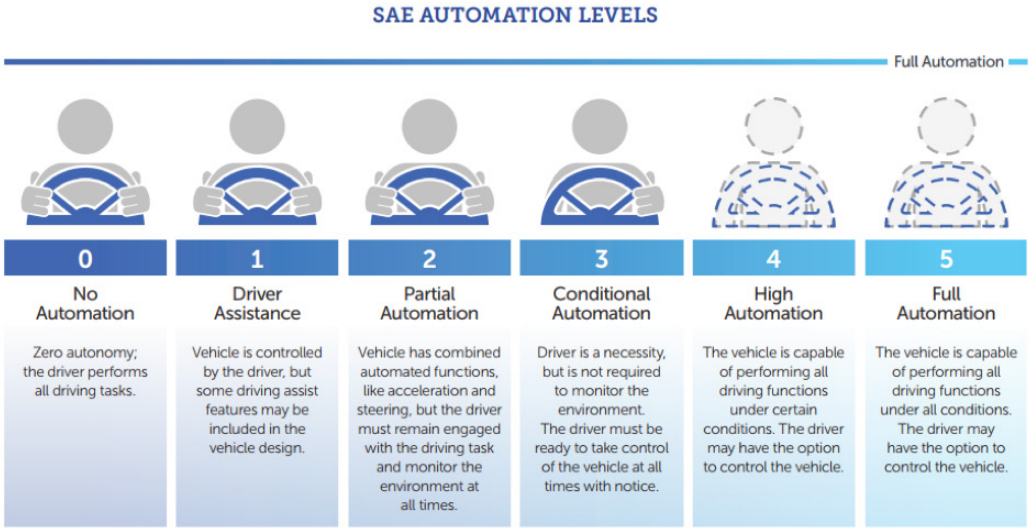
50 Michael Copeland, "What's the Difference Between Artificial Intelligence, Machine Learning, and Deep Learning?," NVIDIA, July 29, 2016, https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/.

Society of Automotive Engineers International Levels of Motor Vehicle Driving Automation Systems (SAE Levels of Automation) is the most widely industry-accepted taxonomy that ranges from no automation (Level 0) to full driving automation (Level 5). It describes the full range of driving automation features on motor vehicles in a functionally consistent manner. A given vehicle can have several automation features; therefore, automation levels are not assigned to individual vehicles. The levels are differentiated by "who" monitors the driving environment and whether the human or the automated system is expected to be the safety fallback if things go wrong or the system reaches its limits. (See below).

In an effort to maintain consistency with industry standard SAE J3016, the National Highway Transportation Safety Administration's (NHTSA's) most recent policy, Automated Driving Systems 2.0 (September 2017), replaces the term automated vehicles with automated driving technologies and highly automated vehicles with automated driving systems.

An automated driving system (ADS) is the hardware and software that is collectively capable of performing the entire dynamic driving task on a sustained basis, regardless of whether it is limited to a specific operational design domain. ADSs may include systems for which there is no human driver or for which the human driver can give control to the ADS and would not be expected to perform any driving-related tasks for a period of time ADSs include SAE Levels of Automation 3–5 (NHTSA).[51]

Autonomous vehicle—There is little consistency in the use of the term autonomous vehicle, and as such, the NHTSA recommends against using it. Colloquially, it is any vehicle that drives itself. Some writers use it as an umbrella term for SAE Levels of Automation 1–5 above, others in reference only to fully autonomous vehicles, still others for an array of levels. Perhaps most typically it refers to SAE Levels 4 and 5, where the vehicle can perform all driving functions, at least under certain conditions, which is how it is used in this paper.



51 United States Department of Transportation National Highway Traffic Safety Administration. "Automated Driving Systems 2.0: A Vision for Safety," September, 2017.

09

Terminology Related to Disruptive Motor Vehicle Technology (cont.)

Smart driving cars is an umbrella term used to describe the type of automation technology that includes safe-driving cars (and trucks and buses), self-driving cars, and driverless cars. Each describe the problem the technology tries to address and the specific business case for that technology. They do not describe a progression of technological development. The types of technologies below do not neatly correspond to SAE Levels of Automation discussed above. Each offers its own set of benefits.[52]

Safe-driving cars introduce enhanced safety technology into cars driven by humans. For example, these technologies include automated driver assistance systems, such as collision avoidance and lane centering.

Self-driving cars allow drivers to take their hands off the wheel and feet off the pedals in some driving environments at some times. The focus of this technology is on the comfort and convenience of the driver. Some vehicles may also come with safe-driving technology, but that is not always the case. Tesla's self-driving autopilot does not have an automated emergency braking system, a fundamental element of a safe-driving car.

Driverless cars drive themselves the whole way from some origins to some destinations over some routes at some times and, as such, can operate completely empty with no human on board in those situations. Driverless cars include both safe-driving and self-driving technology.

Connected Vehicle Technology

Connected vehicles (CVs) use short range wireless communication to share information with the following:

» Other vehicles through ***vehicle-to-vehicle communication (V2V)***

» Infrastructure through ***vehicle-to-infrastructure communication (V2I),***

» Pedestrians through ***vehicle-to-pedestrian communication (V2P)***

V2X references both V2V and V2I communications, and sometimes V2P. ***X2X*** refers to various combinations of wireless communications among vehicles, other road users, and the surrounding infrastructure.

CV technology communicates data related to vehicle speed, location, and trajectory; infrastructure; and other operational and safety variables. The technology potentially enables better real-time traffic management. Automated driving systems and connected vehicle technology are not the same, but may be complementary.

OEM, the acronym for original equipment manufacturers, is a company that manufactures new motor vehicles or motor vehicle equipment.

52 Alain Kornhauser, http://smartdrivingcar.com/.

09

Other Terminology

Autonomous vehicle platooning is part of a suite of features that self-driving and driverless cars might employ to allow a group of vehicles to travel very closely together at high speed. Each vehicle communicates with the other vehicles in the platoon. There is a lead vehicle that controls the speed and direction, and all following vehicles (which have precisely matched braking and acceleration) respond to the lead vehicle's movement. More colloquially, platooning simply refers to a chain of vehicles that travel very closely together. Some bicycle and pedestrian advocates have suggested that long platoons of AVs, especially in urban environments with long distances between traffic lights, could pose barriers to street crossing.

Active transportation refers to any form of human-powered transportation, including walking, cycling, using a wheelchair, in-line skating, and skateboarding.

Bikeshare refers to a service in which bicycles are made available to individuals for shared use on a very short-term basis (e.g., 30 minutes) for a price.

> ***Dock-based bikeshare systems*** allow users to pick up and return bikes from any technology-enabled dock or station located throughout a service area.
>
> ***Dockless or GPS-based bikeshare systems*** put GPS technology directly into the bikes themselves as opposed to the docks, enabling users to essentially park them anywhere.

Carshare is a service that provides members with access to an automobile for short-term—usually hourly—use. Types of carsharing include round-trip, one-way, point-to-point, peer-to-peer, and niche (e.g., Flightcar, which allows travelers to rent out the private vehicles they've left behind in airport parking lots, or closed-network systems, such as those used by universities).

Delivery robots, also called personal delivery devices, are devices powered by an electric motor, for use primarily on sidewalks, and capable of transporting items with or without an operator directly controlling the device.

Demand responsive transportation (DRT) is a set of public and private services where individual passengers can request transportation from a specific location to another specific location at a certain time. Vehicles do not follow a fixed route.

Human services transportation (see Specialized transportation)

Microtransit refers to information technology (IT)-enabled private multipassenger transportation services, such as Chariot and Via, that serve passengers using dynamically generated routes on demand. Passengers may be expected to make their way to and from common pickup or drop-off points. Vehicles can range in size from large SUVs and vans to shuttle buses. Because they provide transit-like service on a smaller, more flexible scale, these new services have been referred to as *microtransit*. The dynamic route-generating technology used by many of these services also has tremendous potential for modernizing public transit and paratransit services.

Mobility Management (three perspectives). In the new transportation ecosystem, all forms of mobility management will need to come together to offer all customers more seamless travel options.

> ***The human services perspective.*** Mobility management is a customer-centered approach to designing and delivering mobility services to individuals with special needs due to age, disability, or income. Mobility managers provide information about community and regional transportation services in order to help their clients access those services.
>
> ***The transportation planning perspective.*** Mobility management entails the essential role the public sector must play in managing the tremendous amount of choice in travel today. While human services professionals view the role of mobility managers as connecting older adults, people with disabilities, and low-income individuals to appropriate transportation services, transportation planners have the general population in mind when they refer to mobility management.

The tech world perspective. Mobility management involves combining an individual's specific travel history and current circumstances with data from millions of others and information from different modes of travel across the city. Applying advanced analytics to big data, these companies offer customers tailored, seamless options.

Mobility as a Service (MaaS)— In its narrowest sense, MaaS describes a shift away from personally owned modes of transportation and toward mobility solutions that are consumed as a service, often on demand. A more expansive view of MaaS is one in which a variety of services are made available to customers through a single platform, where users can identify their travel options, evaluate the cost in terms of both dollars and time, schedule a ride, monitor progress, and even pay for the end-to-end journey regardless of the number of transfers and independent providers used. This platform would include both on-demand and fixed-route public transportation service. The concept is similar to a search engine that provides flight options and a payment mechanism for multiple carriers (e.g., Expedia).

Universal Mobility as a Service (see definition above)—*Universal* MaaS expands upon the concept of MaaS even further by adding the concept of universality to ensure that all users' needs are met, regardless of income, geographic location, disability, or age. Universal refers to both a comprehensive inclusion of all available transportation services within the platform and accessible design throughout the system. Travel options include specialized transportation (see definition below). All aspects of the Universal MaaS framework abide by the principles of universal design. The Universal MaaS platform shows customers their fixed-route and demand responsive public transportation options. On-demand transportation, traditionally limited in the United States to those who own their own vehicles, now may include microtransit, ridesourcing, ridesharing, carsharing, and bikesharing. The platform could even integrate volunteer transportation services. While services tailored to the needs of particular populations will be available, they will be part of a single, coordinated system that as a whole meets the needs of everyone in the community regardless of income, geographic location, disability, or age.

On-demand transportation refers to a service available immediately. Lyft and Uber are examples of on-demand transportation. Trips that require 24- or 48-hour advance reservations are not.

Open source refers to something people can modify and share because it is intended to be publicly accessible. The term originated in the context of software development where the source code is such that anyone can inspect, modify, and enhance it, provided they sign the open-source license. Open-source software and applications are often developed in a public, collaborative manner. Open-source software, algorithms, and platforms by definition are not proprietary.

Public transportation includes buses, subways, light rail, commuter rail, monorail, passenger ferry boats, trolleys, inclined railways, and people movers. Federal law defines public transportation as regular, continuing, shared-ride, surface transportation service that is open to the general public or open to a segment of the general public defined by age, disability, or income level. It can be provided through fixed-route, *demand responsive,* or *on-demand* service.

Real-time information is transmitted and delivered to reflect current status as much as possible (as opposed to published schedule information).

Ridehailing is a service provided by a taxicab company whereby a customer hails a cab from the curb. Some writers erroneously refer to ridesource companies as ridehailing. By local ordinance and company policy, ridesource companies may not obtain customers in this way. Ridesource customers must reserve a ride through an app.

Ridesharing adds additional passengers to a preexisting trip. Such an arrangement provides transportation options for riders while allowing drivers to fill otherwise empty seats in their vehicles. Unlike ridesourcing, ridesharing drivers are not "for hire," but may be compensated for their time and/or mileage. Forms of ridesharing include the following:

Carpooling involves travelers riding together to save on fuel and operating costs, and can be arranged among known or unknown parties. This should not be confused with carsharing.

Vanpooling is often run by transit or other public agencies and facilitates groups of commuters (often coworkers) to share a ride. Vanpooling is similar to carpooling, but on a larger scale.

Real-time or dynamic ridesharing matches drivers and passengers based on destination through a mobile app before the trip begins. The passenger often pays a share of the trip cost. Rideshare apps such as Blablacar have become immensely popular in Europe, but have been slow to attract users in the United States. One US example is the CarpoolNow mobile app offered to Washington, DC-area commuters by the Council of Governments.

Roadside ridesharing is the rebranded term for "hitchhiking."

Ridesourcing providers, such as Lyft and Uber, use online platforms to connect passengers with compensated drivers who use personal vehicles. California law codifies these services as *transportation network companies (TNCs)*.

Ridesplitting is when ridesource customers share a vehicle and split the cost of the ride, proportional to their trip length.

Shared-use mobility is a term used to describe transportation services that are shared among users, including public transit, taxis and limos, bikesharing, carsharing (round-trip, one-way, and personal vehicle sharing), ridesharing (carpooling, vanpooling), ridesourcing, scooter sharing, shuttle services, neighborhood jitneys, and commercial delivery vehicles providing flexible goods movement.

Specialized transportation is services tailored to meet the needs of older adults and people with disabilities, often through door-to-door or door-through-door paratransit services, which have been traditionally provided on request by van, small bus, or taxi. Various human services providers arrange this form of transportation for their clients. They are typically demand responsive services and are also known as human services transportation.

Transportation network companies (TNCs)— see Ridesourcing.

Universal design is the design of buildings, vehicles, environments, products, services, and user interfaces that are broadly accessible to people with disabilities, older people, young children, and everyone else. It is a rejection of the notion that things be designed for the "average" person, which too often results in separate facilities for people with disabilities—for example, a ramp set off to the side of a stairway or a separate paratransit bus service. Universal design, on the other hand, provides one solution that can accommodate everyone.

A ***white-label*** product is a product or service produced by one company (the producer) that other companies (the marketers) rebrand to make it appear as if they had made it.

10 Bibliography

Arbib, James, and Tony Seba. 2017. "Rethinking Transportatation 2020-2030: The Disruption of Transportation and the Collapse of the Internal-Combustion Vehicle and Oil Industries." A RethinkX Disruption Report, May. https://www.rethinkx.com/executive-summary/.

Autotrader. "Automated vs. Autonomous Vehicles: Is There a Difference?" 2018. https://www.autotrader.com/car-news/automated-vs-autonomous-vehicles-is-there-a-difference-273139.

Bank of America, Merrill Lynch, Global Automobiles. "Mobility Services: Reducing Car Ownership and Car Usage." June 21, 2017. https://research1.ml.com/Archive/11757001.pdf?q=a15W4r9Z-v!R8r8HlTiSaTg&__gda__=1508794335_a821117f54de939d6220318b63588028.

Barr, Joseph. 2017. "Transportation Communications: No One Told Me It Would Be This Hard." Meeting of the Minds, August 17. Accessed February 13, 2018. http://meetingoftheminds.org/transportation-communications-no-one-told-hard-22315?utm_source=Meeting+of+the+-Minds+Newsletter+List&utm_campaign=09dfa28dfa-RSS_EMAIL_CAMPAIGN&utm_medium=email&utm_term=0_cdb70a5ce7-09dfa28dfa-57905337&mc_cid=09dfa28dfa&mc_ei.

Bureau of Transportation Statistics. 2011. "The U.S. Rural Population and Scheduled Intercity Transportation in 2010: A Five-Year Decline in Transportation Access." February.

Claypool, Henry, Amitai Bin-Nun, and Jeffrey Gerlach. 2017. "Self-Driving Cars: The Impact on People with Disabilities." (Ruderman Family Foundation and Securing America's Future Energy).

Commuter Connections. 2016. "State of the Commute Survey 2016 ." June 30.

Copeland, Michael. 2016. "What's the difference between articial intelligence, machine learning, and deep learning?" NVIDIA. Accessed February 6, 2018. https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/.

Corwin, Scott, Nick Jameson, Derek M. Pankratz, and Phillipp Willigmann. 2016. The Future of Mobility: What's Next? Deloitte University Press.

Curtis, Terra, and Josh Karlin-Resnick. 2016. "Autonomous Vehicles and the Future of Parking." Fall. Accessed February 19, 2018. http://nelsonnygaard.com/wp-content/uploads/2017/04/AutoVeh_FutureParking_FINAL.pdf.

Diehl, Daleb. 2018. "The Transporter." Oregon Business, January 23. Accessed March 22, 2018. https://www.oregonbusiness.com/article/transportation/item/18172-the-transporter.

EMC Research. 2017. "Commute Seattle Mode Split Survey Results." Accessed November 10, 2017. https://commuteseattle.com/modesplit/.

Foley , Daniel J., Harley K. Heimovitz, Jack M. Guralnik, Dwight B. Brock, "Driving Life Expectancy of Persons Aged 70 Years and Older in the United States," American Journal of Public Health, Vol.92, No. 8, August 2002.

Hawkins, Andrew J. 2017. "This map shows how few self-driving cars are actually on the road today." The Verge. https://www.theverge.com/2017/10/23/16510696/self-driving-cars-map-testing-bloomberg-aspen.

Henderson, Susan, and Marilyn Golden. "Self-Driving Cars: Mapping Access to a Technology Revolution." National Council on Disability, November 2, 2015. https://ncd.gov/sites/default/files/NCD_AutomatedVehiclesReport_508-PDF.pdf.

Huston, Caitlin, "Why General Motors Invested in Lyft," MarketWatch, January 4, 2016, https://www.marketwatch.com/story/why-general-motors-invested-in-lyft-2016-01-04.

Insurance Institute for Highway Safety. 2016. "Driver Seat: Robot Cars Won't Retire Crash-Test Dummies Anytime Soon." (Highway Loss Data Institute) Vol. 51 (No. 8).

Interrante, Erika. 2014. "The Next Generation of Travel: Research, Analysis and Scenario Development." Accessed February 13, 2018. https://www.fhwa.dot.gov/policy/otps/nextgen_finalreport.cfm.

Kerry, Cameron F., and Jack Karsten. 2017. "Gauging Investment in Self-Driving Cars." (Brookings Institution). Accessed November 27, 2017. https://www.brookings.edu/research/gauging-investment-in-self-driving-cars/.

Kerschner, Helen K., and Nina M. Silverstein. 2018. Introduction to Senior Transportation. New York: Routledge, Taylor & Francis.

Litman, Todd. "Autonomous Vehicle Implementation Predictions: Implications for Transportation Planning." Victoria Transport Policy Institute, 2017.

—. 2017. "Public Transit's Impact on Rural and Small Towns: A Vital Mobility Link." October.

Lynott, Jana. "Creating the Transportation System We Want: Building Blocks for the Road Ahead." AARP Public Policy Institute, Washington, DC, 2018. www.aarp.org/ppi/issues/livable-communities/transportation/future-of-transportation/.

Lynott, Jana. "Reconnecting Small-Town America by Bus: New Federal Transit Rules Spur Investment." AARP Public Policy Institute, Washington, DC, 2014. https://www.aarp.org/ppi/issues/livable-communities/info-2015/rural-transit-video.html.

Lynott, Jana. "Video: Rural Transit Connects." AARP Public Policy Institute, Washington, DC, 2014. https://www.aarp.org/ppi/issues/livable-communities/info-2015/rural-transit-video.html.

Mervis, Jeffrey. 2017. "Are We Going Too Fast on Driverless Cars?" Science, December 14. Accessed February 15, 2018. http://www.sciencemag.org/news/2017/12/are-we-going-too-fast-driverless-cars.

Mattson, Jeremy. 2017. "Rural Transit Fact Book 2017, Table 14." October. Accessed February 13, 2018. https://www.surtc.org/transitfactbook/downloads/2017-rural-transit-fact-book.pdf.

Morris, David Z. 2016. "Today's Cars Are Parked 95% of the Time." Fortune. http://fortune.com/2016/03/13/cars-parked-95-percent-of-time/.

National Association of City Transportation Officials. "Blueprint for Autonomous Urbanism, Module 1." 2017. https://nacto.org/publication/bau/blueprint-for-autonomous-urbanism/.

National Association of City Transportation Officials. "NACTO Policy Statement on Automated Vehicles." 2016. https://nacto.org/wp-content/uploads/2016/06/NACTO-Policy-Automated-Vehicles-201606.pdf.

National Governors Association, National Conference of State Legislatures, American Association of Motor Vehicle Administrators, American Association of State Highway & Transportation Officials, and Governors Highway Safety Association. "Letter to U.S. House and Senate Leadership." 2017. http://www.ncsl.org/ Documents/standcomm/scnri/Final_State_House_AV_Bill_9.5.pdf.

Newcomb, Doug, "How Daimler Is Tying Together Its Diverse Mobility Investments," Forbes, May 30, 2018, https://www.forbes.com/sites/dougnewcomb/2018/05/30/how-daimler-is-tying-together-its-diverse- mobility-investments/#4977483e3215.

Pew Research Center. 2018. "Mobile Fact Sheet." February 5. Accessed May 22, 2018. http://www.pewinternet.org/fact-sheet/mobile/.

Rosenbloom, Sandra, and Jana Lynott. "Transportation Funding Reform: Equity Consideration for Older Americans." AARP Public Policy Institute, Washington, DC, 2011.

Schmitt, Angie. 2016. "Where Car Commuting is Shrinking, and Where it's not." Streetsblog USA, September 16. http://usa.streetsblog.org/2016/09/16/where-car-commuting-is-shrinking-and-where-its-not/.

Schneider, Benjamin. "D.C. Gives Uber and Lyft a Better Spot in Nightlife." Citilab, 2017. https://www.citylab.com/transportation/2017/10/a-dc-neighborhood-rethinks-parking/543870/.

Schweiger, Carol. "Bringing Mobility as a Service to the United States: Accessibility Opportunities and Challenges." National Aging and Disability Transportation Center, n.d.

Teal, Roger, Niels Tvilling, Charlotte Frei, Candace Brakewood, David Chia, and David King. "Development of Transactional Data Specifications for Demand-Responsive Transportation." Transit Cooperative Research Pogram, Transportation Research Board, January 2018. http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4120.

transpogroup. "Autonomous Vehicle Policy Framework Summit: Final Product Report." January 2018. http://www.transpogroup.com/avpolicysummit.html.

UCL Energy Institute. "Video: Understanding the Benefits of MaaS." Intelligent Transportation 2016. https://www.intelligenttransport.com/transport-articles/21270/video-understanding-maas/.

Union of Concerned Scientists. "Maximizing the Benefits of Self-Driving Vehicles." 2018. www.ucsusa.org/avprinciples.

United States Department of Transportation National Highway Traffic Safety Administration. "Automated Driving Systems 2.0: A Vision for Safety," September, 2017.

Wallace, Richard. et al. 2005. "Access to Health Care and Nonemergency Medical Transportation: Two Missing Links." Transportation Research Record: Journal of the Transportation Research Board, 76-84.

"What will car ownership look like in the future?" Quora contributor to Forbes. Accessed September 1, 2017.

Zohdy, Ismail, et al. 2016. "Impacts of Millennial Student Loan Debt on Transportation Choices." September. Accessed February 13, 2018. https://www.fhwa.dot/gov/policy/otps/millennial_travel_choices.pdf.

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