THE FUTURE OF RURAL TRANSPORTATION AND MOBILITY FOR OLDER ADULTS:

Current Trends and Future Directions in Technology-enabled Solutions

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INTRODUCTION

Technology has been a transformational agent in the way that people live, work, and socialize. The impact of current technology trends on transportation and personal mobility are no different given our anticipation of how technology will influence the movement of people and goods.[1] Urban centers have become innovation test-beds for technology-enabled mobility services as part of smart city planning and development. The rural transportation landscape has received comparatively less attention and funding for related research and development. This is in part due to the perception of a lack of economic feasibility as well as logistical challenges on the basis of these communities simply being rural. The net effect has been that change at a system level has been slow. The pockets of innovation that exist underscore the reality that each community is unique in its needs and resources, and that the social and cultural context of managing change is central to the technology adoption and implementation process.

The focus and scope of this white paper is on the transformation of mobility for older adults in rural communities through technological innovation in transportation solutions. Driving forces that are shifting how society thinks about transportation and mobility and thus impacting technology-enabled transportation services include: increasing consumer expectations for on-demand services with the high levels of smartphone and internet penetration; the customization of services to the individual while meeting the needs of all travelers; and collaborative service models that support real-time data capture and management, and the automated exchange of multimodal transportation data.[2] [3] As a result, technology has been a key enabler in reducing transportation service gaps and operational inefficiencies for older adults who rely on public transit services, while also providing connectivity for older adults to access online information-based services on public transit. Technological innovation has also been key to improving in-vehicle accessibility and safety for older adults who still drive,

The application of technology-enabled innovations to advance transportation solutions and expand mobility options can sometimes seem ripped from the pages of science fiction. Early signs of that technology-enabled future are emerging with autonomous-vehicle, drone, and telepresence technologies. In practice, however, technology is but a part of the total solution when realizing an envisioned future. As is often the case with emerging and oftentimes unproven technologies, the development of an enabling market infrastructure in the form of standards, regulations and laws for their commercialization is going to be critical. The social aspects of technology-led change are also important considerations as catalysts for technological change in rural transportation. Importantly, initiatives that create greater awareness of older adults' transportation challenges among the technology community as well as of technology's potential among rural transportation community stakeholders are likely to create opportunities for cross fertilization to occur within the rural transportation field.

BACKGROUND

Research Objectives

The focus and scope of this white paper is on the transformation of mobility for older adults in rural areas through technological innovations. The white paper explores the potential for technology research and innovation to transform the rural mobility landscape and, in the process, empower older Americans through meeting their travel needs in an equitable and effective manner. Potential solutions may improve the operational efficiency of public transit services through improved scheduling, coordination and management, overcome in-vehicle accessibility barriers that older adults experience when using transportation solutions, or improve overall transportation safety through *intelligent* infrastructure developments. Solutions may also involve shifting the focus from needing to transport older adults to facilitating the delivery of alternative, supplementary services directly to them, whether that is consumer goods, healthcare services, or simply direct human contact.

The white paper assesses future rural transportation solutions and personal mobility options through providing an overview of technology drivers and advances from three perspectives: [4]

- **Current state** in terms of the transportation diversity resulting from the role of technology in facilitating improved coordination and scheduling of various modes (e.g., public transit; ridesharing; ride-hailing) as well as in providing mobility management service benefits through customizing trips according to individual user needs.

- **Emerging state** in terms of large-scale technology infrastructure developments in intelligent transportation systems (ITS) and broadband to enable future opportunities for innovation in mobility solutions (e.g., connected vehicles) and mobility supplements (e.g., telehealth) for rural areas.

- **Plausible futures** on a longer timeline horizon assesses innovations in potentially disruptive products and services (e.g., autonomous vehicles, drone delivery) and innovative business models (e.g., mobility as a service) given how we today conceive of and approach transportation challenges and personal mobility needs in rural areas.

The potential role of technology in realizing any future vision of mobility for older adults in rural areas is best understood at first by defining the needs of populations to be served, the contextual challenges with providing transportation solutions in rural communities, and the availability of resources locally to effectively meet those needs. [See Table 1: By the Numbers: Rural Communities Older Adults, and Travel Behaviors] How federal, state and local governments prioritize investments in infrastructure and services to advance transportation in rural settings will affect the types of technology-enabled innovations that are considered and the timing for their deployment. Today,

investment in maintaining and upgrading the current physical transportation infrastructure (i.e., road markings, signage) is viewed as a near-term opportunity for technology-enabled autonomous vehicle applications. In the longer term, investments in large-scale technical infrastructure to support connectivity and interoperability between vehicles and the transportation infrastructure will serve as the foundation for more potentially disruptive, technology-enabled innovations in transportation products and services.

Table 1: By the Numbers: Rural Communities, Older Adults, and Travel Behaviors

- Rural areas cover 97 percent of U.S. land area but contain about 19 percent of the population (about 60 million people).[5] Nearly half (46.7 percent) of all people living in rural areas are in the South (about 28 million people). Maine and Vermont have the highest proportions of the state population living in rural areas (about 61.0 percent) and California the lowest (4.9 percent).[6]

- Approximately 17 percent of adults in rural areas are 65 or older.[7] Between 2011 and 2015, about 9 percent of the rural population (5.3 million) lived in 704 completely rural counties (100.0 percent lived in rural areas), about 41 percent (24.6 million) in the 1,185 mostly-rural counties (50.0-99.9 percent), and 50 percent (30.1 million) in the 1,253 mostly-urban counties.[8]

- The median age of all people living in rural areas is 43 years, compared with 36 years for urban areas.[9] Rural adults in the completely rural counties tend to be older than rural adults in the mostly-rural and mostly-urban categories. As the rurality of a county increases, the percentage of rural adults who live alone increases, while the percentage who are currently married decreases.[10]

- Today, adults over the age of 65 on average drive half the amount of those aged 25 to 64. In the future, an increasing number of older adults may depend more on transportation as they work later in life and travel more often.[11] As adults age, however, their tendency to drive privately-owned vehicles decreases and to ride as a passenger increases.[12]

- Nearly half (49 percent) of all traffic fatalities and serious injuries occur in rural areas. Starting at age 75, fatal crash rates increase per mile traveled, primarily due to an individual's increased susceptibility to injury and medical complications.[13] Functional limitations, cognitive function, and measures of vision are significant predictors of driving cessation longitudinally.[14]

- The US predicts a 77 percent increase among drivers over 65 by 2045.[15] Of the 221.7 million licensed drivers in the U.S. in 2016, the 65 years or older age group

is growing the fastest (41.7 million licensed drivers). The largest single-year percentage increase in licensed drivers was among those between 75-79 years old, and the second-fastest growing demographic group was individuals aged 85 or older.[16]

- Older adults are more reliant on driving than urban counterparts, especially males, but current demographic trends suggest that in the future many will outlive their ability to drive. As people age, particularly past 75 years, their driving ability tends to decline. By choice or necessity, many older Americans adjust their routines and rely increasingly on alternative transportation options.[17]

- An older adult who cannot drive is immediately at increased risk for reduced activities that places them at a greater risk for adverse health outcomes. Approximately 13 percent of rural seniors have no vehicle.[18] Older adults who stop driving take15 percent fewer trips to the doctor, 59 percent fewer shopping trips, and 65 percent fewer social, family, religious and other life-enhancing trips.[19]

- Nationwide, 81 percent of counties had some level of rural transit service in 2014.[20] Eleven percent of rural households report having access to transit services[21], and 40 percent of rural residents report living in counties with no public transportation services.[22] Despite population decline in rural areas, rural transit ridership per capita increased 8.6 percent and total rural ridership by 7.8 percent between 2007-15.[23]

- In 2014, public transit agencies in rural areas represented about 1.5 percent of national passenger trips, and non-profit senior citizen and persons with disabilities transit service providers less than 0.5 percent of all national passenger trips. Demand-response services, operated by non-profit providers for older Americans and persons with disabilities, represent the majority of rural transit systems by mode (89 percent).[24]

- One-quarter (24-27 percent) of rural residents are able to access different amenities by public transit, compared to just under three-quarters (71-74 percent) of urban and half (44-47 percent) of suburban residents. A higher percentage of medical trips in rural areas is made by transit (7.4%) compared with non-transit trips (2.4%). In areas with a population below 200,000, 8.6% of transit trips are for medical purposes. [25]

- Rural counties are 10 times as likely as urban areas to have low broadband access, be co-located in high diabetes areas, and to experience physician shortages that are more than double the national average.[26] Rural counties with more limited adoption are in the sparsely populated settled counties (e.g., Great Plains, Nevada, New Mexico) as well as high-poverty, high-minority regions (e.g., tribal lands in the West).

Research Methods

The research methodology includes an environmental scan of peer-reviewed articles and the gray literature for developments in transportation technology, innovation, best practices, and public policy. Interviews with more than 30 subject matter experts were also conducted. Subject matter experts (see Acknowledgements section) were asked a set of standard questions and their responses were recorded. It is anticipated that transportation will continue to evolve with developments in enabling technologies, particularly in areas related to communications, sensors, and artificial intelligence. The underlying market infrastructure as well as evidence of best practices will be equally critical in promoting innovation and advancing the adoption of technology-enabled transportation services and personal mobility solutions during the next 20 years.

PROBLEM-DEFINED: RURAL TRANSPORTATION FOR OLDER ADULTS

The United States is projected to experience a doubling in the over-65 year old population between 2010 and 2050. However, the functional abilities of older adults within this age group can vary significantly as well as impact differently individual traveler's needs, capabilities, and experiences.[27] There is a positive correlation between successively older age groups and their risk of developing a disability or chronic condition which can increase their need for assistance with activities of daily living. In particular, aging-related conditions can impair mobility and adversely affect health (e.g., depression, cardiovascular disease, cancer, and injuries), reduce access to critical goods and services, and limit social contact. As a result, mobility restrictions older adults may experience as they age can not only adversely impact their health status when it prevents their access to critical medical services but also their quality of life due to their inability to engage and participate fully in community life.

> **Mobility restrictions have consequences for the health and well-being of older adults, which often result in a cascade effect of continuing deterioration.**
>
> —CDC's Healthy Aging Research Network[28]

The transportation needs of older adults in rural areas are multifaceted and represent a confluence of challenges that are geographic (e.g., sub-optimal road and telecommunications infrastructure; long travel distances for access to local services); population-based (e.g., loss of the ability to drive with increasing age; low population-density and low demand for services; cultural norms and values); and structural (e.g., small tax base to fund services; limited service availability and coordination between systems; lack of public access to transit service information; limited funding and resource scarcity).[29] While the rural transportation issue for older adults is not new, the challenges will become more acute with demographic changes in the coming decades.

Importantly, access to equitable transportation services will be a necessity to support the ability of older adults in rural areas to both remain healthy and live independently in their communities.

Interest in the future of transportation and personal mobility for older adults in rural areas is driven by today's challenges with providing transportation alternatives to driving while effectively meeting the basic mental, physical, and emotional well-being needs of individual users in an equitable, inclusive, and effective manner. Today, technology is helping to address service gaps due to geographical challenges in their delivery. The proliferation of Internet capabilities and emergence of location-based services as solutions to first mile/ last mile transportation gaps is enhancing service offerings, while smartphones and data systems are facilitating improved user experience through providing consumer access to real-time, integrated transit information services. It is imperative for transportation service providers to continue to leverage these technologies while remaining flexible to accommodate future technological developments that can address the mobility and connectivity challenges experienced by older adults. It is also important to ensure older adults' equitable access to digital platforms and devices that can offer expanded mobility service options.

Breaking this path-dependency of road-based car travel remains a key innovation challenge.

—The Strategic Transport Research and Innovation Agenda, European Union[30]

Problem-Defined Solutions

The approach to solving rural transportation challenges varies by community on the basis of user needs, resource availability, and political will. Access to transportation for older adults in rural communities is a leading priority, and healthcare represents a major service need that older adults have for transportation. Without access to transport, older adult rural populations are more likely to delay medical appointments, preventive care, and health maintenance activities, and are more vulnerable to social isolation, which can lead to an increased risk of morbidity and mortality.[31] The expectation that an increasing number of older adults will experience longer life spans as they age, and potentially without any accompanying reductions in their risk for developing a disability or chronic condition, suggests that a larger number of older adults, many of whom will live in rural communities, will outlive their ability to drive and increasingly depend on alternative means of transportation for access to healthcare services. This situation calls for innovative approaches to the development of transportation solutions that meet the healthcare needs of older adults and that are sustainable within the rural context.

Medical transportation is often the highest priority for transit programs targeting older adults within any community. Medicaid requires states ensure transportation for eligible beneficiaries, with several federal government agencies (i.e., the Centers for Medicare and Medicaid, Federal Transit Administration and Administration for Community Living)

providing core funding for specialized transportation services. Older adults who can no longer drive pose considerable operational challenges to transit agencies that provide specialized medical transportation services. The more critical the medical service needs of older adults, such as kidney dialysis, the more challenging it can be for agencies to maintain efficient, reliable, and viable services on a regular basis. The average trip for medical and dental services is about nine miles longer in rural than urban regions.[32] A specialized transit model, especially one that is focused on a narrow population and use case, is a potential shortcoming when assessing the feasibility of innovative technology-enabled transportation solutions and mobility options in rural communities. Ideally, solutions that address broader mobility needs within the community and provide more broad-based benefits for older adults present opportunities to realize greater economies of scale as well as offer the potential for sustainability and replication.

Access to transportation in rural communities represents a social determinant of rural health and aging well. The development of equitable transportation solutions as a basic right constitutes a strategy for reducing disparities and improving the livability of a community. At the local level, communities have responded to transportation service challenges and older adults' needs by adopting creative and customized approaches to the development of local solutions. The formation of partnerships and pooling of assets and resources in a shared solution model, for example, have enabled local communities to create greater diversity in local transportation services. However, realization of the greater potential for the transformation of rural transportation through innovation and technology still depends on federal and state funding as well as public policy as key enablers. Since funding can often be limited, rural strategies that seek to leverage technology-enabled innovations need to balance the required investments with the potential benefits to be realized through improved accessibility and affordability of transit services for targeted populations as well as improved public safety from road infrastructure maintenance and upgrades.[33] Technology-enabled innovations at the regional rather than local level may be more effective in realizing superior economies of scale.

RURAL TRANSPORTATION LANDSCAPE: THE ROLE OF TECHNOLOGY-ENABLED INNOVATION

A key driver of innovation to advance rural transportation solutions and mobility options for older adults involves reframing the discussion. By broadening the strategic focus from the intersection of transportation with health to viewing transportation as a social determinant of rural health, the targeted objective of reducing the inequities and disparities that older adults currently experience could be realized through advancing transportation solutions that promote their full participation and engagement in the community. State and local transportation agencies increasingly use technological innovations to promote integrated transit services and improve performance management through facilitating linkages between different transit modes and connecting specialized transportation customers with information-based services, while offering the potential for a broader set of mobility options beyond *specialized* transportation services.

These linkages, which can provide customers with smartphone-enabled mobility management services, fall along a continuum of functionality levels, with each level offering unique benefits, challenges, and opportunities.[34]

At the local service level, transit operators have deployed software to optimize the management of existing transportation assets through more efficient tracking and scheduling of service vehicles. Rural transit service operators have also been breaking out of traditional siloed operational models and using software to broker greater integration and coordination among the different transit modes (e.g., fixed route; demand-response; ridesharing) available within a community. Rather than introducing new services, existing transportation assets in the community have been redeployed more efficiently and the existing capacity better managed, and users have been able to choose mobility options that best meet their individual needs. As a result, software has helped reduce institutional barriers, overcome jurisdictional boundaries, and eliminate data silos, while spreading the investment cost among participating providers. Real-time data capture and sharing for improved system-level performance management in areas of scheduling and coordination of transit services has helped present a unified service model to customers without diminishing the independence of systems, while improving user experience through facilitating customer access to information-based mobility management services.[35] [36] [37]

Traditional specialized transportation models have functioned as a brokering service that is akin to case management for transportation. The mobility manager, for example, identifies an individual's needs and makes appropriate arrangements for rides that get clients to where they want to go. Mobility on Demand (MOD) has come to prominence as a framework for innovation in mobility where consumers can access goods and services on demand by using an integrated and connected multi-modal network of shared mobility, goods delivery, and public transit service solutions.[38] Under this framework, transportation is viewed as a commodity with individual modes having distinct units of economic value, and the management of supply and demand for services can be handled at the individual through systems level. The supply side consists of the organizations that facilitate transportation services or goods delivery, while the demand side consists of the system users and their choices and preferences. [See Figure 1: MOD Ecosystem] Data governance protocols and standards are critical for the success of MOD to facilitate data sharing and interoperability between participating organizations.[39]

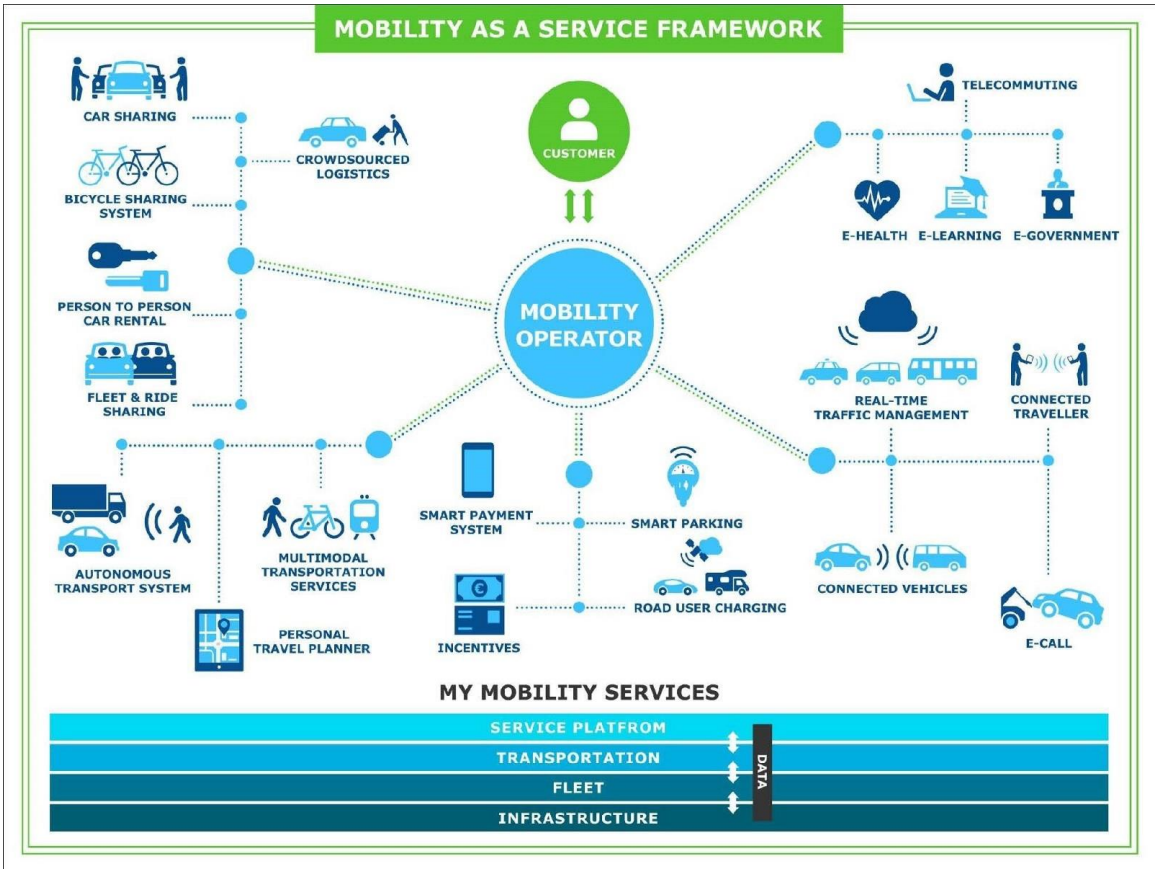
Figure 1: MOD Ecosystem[40]

Source: USDOT, August 2017

Mobility as a service (MaaS) has emerged more recently as a conceptual framework that builds on MOD through the multimodal integration of service infrastructures, information, and fare payments.[41] MaaS could potentially serve as a framework to catalyze public-private co-development and delivery of unified transportation and mobility services, as well as the shared and open use of data and infrastructures.[42] MaaS, which originated in Europe as an urban-centered concept, refers to customizing mobility solutions around individual needs and offering a bundle of flexible travel service options.[43] MaaS differs from MOD by focusing on all users rather than travelers with specialized needs as well as by assuming responsibility for negotiating financial relationships with participating service providers. [See Figure 2: Mobility as a Service Framework) There are currently no MaaS systems in the U.S., but several are under development. Tompkins County (New York) is implementing a MaaS strategy in a rural context to meet the need for integrated mobility solutions that offer access for all community members, while at the same time providing older adults with a system that is

resilient (not subject to budgetary fluctuations), redundant (if one option doesn't work, there is another available), and reliable (users can have confidence that when they give up a car, they will not be isolated). Fostering the political will to champion the adoption of innovative solutions such as MaaS is key to advancing related services.[44] [See Box: Mobility as a Service: Tompkins County]

Figure 2: Mobility as a Service Framework[45]



Source: National Aging and Disability Transportation Center

Mobility as a Service: Tompkins County

Tompkins County (New York), population 104,000, consists of the centrally located Ithaca urban area (population 54,000) surrounded by seven rural towns. A culture of collaboration between local government, institutions of higher education, public transportation and mobility operators and human service agencies promotes innovation and a desire to mobilize stakeholders to address mobility inequity in urban and rural communities.

There is broad interest to develop a Mobility-as-a-Service (MaaS) business model in the county. The objective is to create a market-based, customer-centered, and locally-controlled, full-service reseller of mobility services to the public. Revenue streams would represent a blend of market-rate payments for the majority of the county's residents and public subsidies for persons with limited income and who might otherwise lack access to affordable services. Central to its operation is a mobility coordination center that will enable customers to create and purchase an integrated bundle of mobility services as well as provide customer service to respond to user service needs.

The MaaS model will also serve as a comprehensive information resource for consumer education, outreach, and advocacy around community mobility issues, and will reward providers through providing incentives for continuous improvements in the quality of mobility services.

Ride-hailing or ridesharing services, which have been founded on the operating principles of the broader sharing economy, remain predominantly urban, more broadly adopted by younger populations, and with access often restricted on the basis of affordability. Reasons cited for ridesharing services not being more broadly deployed in rural areas include a perceived lack of consistent demand due to low population density, poor connectivity because of the inconsistency of internet and cell service coverage and, even where services are available, a lack of familiarity if not reluctance among today's older adults to use smartphone technology to book and pay for rides. Transportation network companies have developed workarounds to user concerns, although not necessarily focused on rural users, through the introduction of concierge-like service models that allow users to call an operator to schedule rides on their behalf (i.e., GoGoGrandparent, Lyft, Uber) as well as forming service partnerships targeted at specific use cases (i.e., healthcare service providers). For those rural users with accessibility challenges, accessible transportation options are limited in availability (i.e., uberWAY; uberASSIST; Lift Hero).

A social entrepreneurship model that blended the traditional ridesharing service model with local job creation for its drivers and call center operators (i.e., Liberty Mobility Now) stands out as an example of an innovation that emerged within a rural context to address the broad-based needs of rural communities. It has ceased business for reasons unrelated to its service model but is planning to relaunch as a MaaS-like operator in rural and small urban areas. [See Box: Feonix Mobility Rising]

Feonix Mobility Rising

Valerie Lefler, founder of Liberty Mobility Now (Nebraska), recognizes that the company simply ran out of time and money to prove out its model. A key lesson Valerie learned through that process is that the tech start-up space doesn't always appreciate the nuances of rural transportation. Invaluable lessons learned were that the communities in which the service was available responded favorably to the Liberty

Mobility Now-like model, and that its service model created meaningful employment opportunities and generated income for families.

The bottom line, Liberty Mobility Now spoke to the needs in the community.

So emboldened has Valerie been by these earlier experiences that she and a board of leaders from across the US have launched a non-profit, Feonix Mobility Rising. The organization will focus on bringing more rural communities volunteer driver programs and a mobility management operator - which addresses broader needs with diverse mobility options. The non-profit is connecting with mobility providers and technology companies that will help it expand into other communities through partnerships.

Feonix Mobility Rising plans to launch a mobility management partnership with HealthTran in May 2018.

The widespread installation of broadband connectivity in rural communities will benefit transit services as well as the general community by facilitating improved communication capabilities for both the operational management of transit services and the dissemination of information-based services to the public.[46] Broadband infrastructure will also enable future opportunities for innovation in mobility solutions (e.g., connected vehicles; autonomous vehicles) and mobility supplements (e.g., telehealth).[47] Federal policy will be impactful in advancing funding for large-scale broadband infrastructure development in rural areas, as well as supportive policies that promote the regulation of services (e.g., payment and licensure for professional virtual healthcare services when delivered remotely) and data (e.g., interoperability, privacy, cybersecurity).

Broadband is the new railroad.

—Regional Transportation Planning Organization Peer Exchange (2017) [48]

But not all innovations are created equal. Among the innovations that are emerging, there are those that are relatively low risk and likely to evolve with appropriate levels of investment and supportive policy (e.g., in-vehicle safety, shared ride services). There are others that comprise a higher degree of technical risk that will temper the progress with which they will advance technically but that also raise public concerns on the basis of their novelty (e.g., autonomous vehicles, drone-based delivery services). And there are product and service innovations that we cannot yet anticipate but that are likely to be disruptive given how we currently understand and address mobility challenges for older adults in rural areas today.

THE FUTURE OF RURAL TRANSPORTATION AND MOBILITY FOR OLDER ADULTS

Potentially transformational technology innovations in rural transportation can be broadly organized into several problem-defined solution categories based on the needs of older adults:

- **Improving transportation safety and infrastructure** through the role that ITS and applications of connected and autonomous vehicles will have on public and private transportation.
- **Improving access to transportation** with the emergence of consumer-facing information-based services as well as the evolving continuum of functionality in mobility management service models.
- **Overcoming barriers to transportation** through the availability of broadband and the use of other mechanisms as supplements to surface transportation services for the delivery of goods and services.

Improving Transportation Safety and Infrastructure

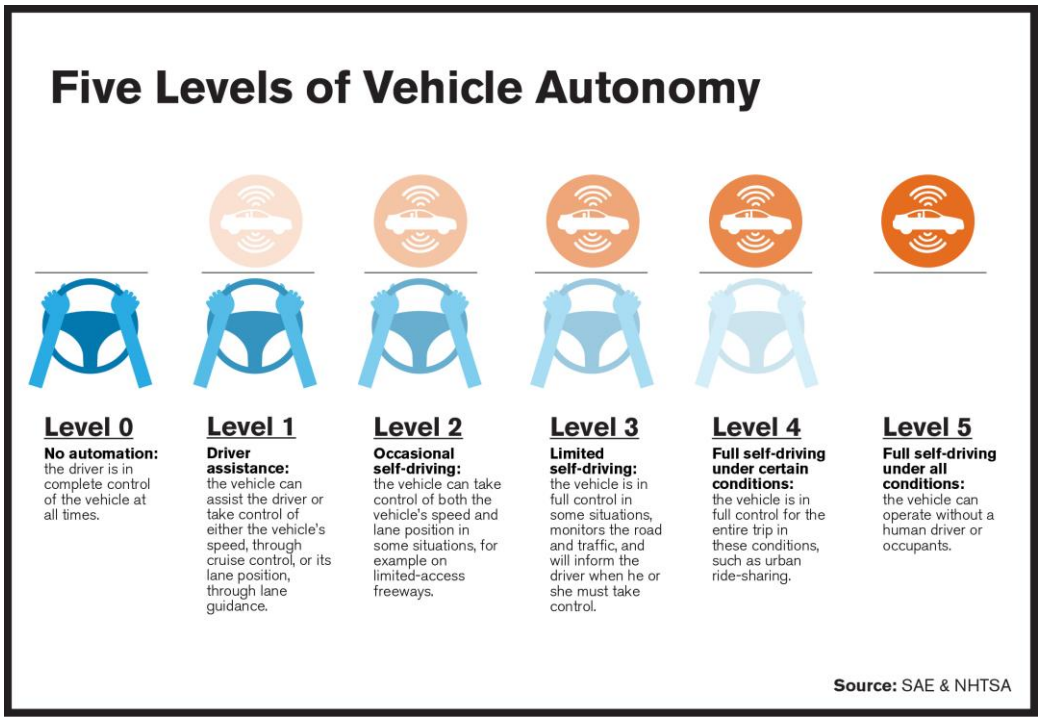
The US Department of Transportation states that the ability to balance individual decision making and system-optimal transportation management is within grasp.[49] Convergence in communication, control, and sensing technology capabilities have been continuously transforming the transportation infrastructure into an intelligent transportation system.[50] Today, ITS serves as the enabling technology foundation for the application of connected and autonomous vehicles Opportunities for vehicle connectivity and automation will be greatly enhanced once vehicles and the ITS infrastructure can operate as a well-integrated system.[51] As a specialized subset of the Internet of Things, ITS-related applications require high-speed wireline and wireless broadband communications infrastructure to optimize real-time performance and impact. The implementation of vehicles with advanced automation capabilities is expected to be more technically feasible in high-density, urban environments before rural settings. However, roll-out and widespread adoption in general will be challenged by the ethical, legal and social implications that applications of AV raise.

As CV technologies advance, greater levels of automation are being gradually introduced into vehicles. The overriding goal is to improve driver safety by actively avoiding crashes and other incidents through reducing the level of human input that is required while increasing the level of autonomous capabilities available. As a result, the tendency for human errors to occur will be significantly reduced and the potential to improve safety for road users, including older adults, increased.[52] [53] The widespread implementation of CV technologies has the potential to reduce non-impaired incidents by over 80 percent.[54] Technologies that will enable successful CV deployments are broadly based on sensor, computing and wireless communication capabilities (i.e., Dedicated Short Range Communications). More specifically, the primary technology applications are centered on facilitating efficient data capture, dissemination, processing and management. Technologies enabling in-vehicle safety applications will, together with innovations in areas related to sensor fusion and processing algorithms, provide the

analytical and decision-support capabilities to support CV collision avoidance applications.[55]

AV technology has the potential to reduce and possibly eliminate vehicle-based crashes and fatalities caused by human error, which currently account for over 90% of fatalities. AVs will also be a significant enabler of MOD[56], with the use of AV initially expected to play an impactful role in specific use cases and operational environments, such as regular closed-loop routes and first mile/last mile services between a fixed-route service point and a traveler's original and/ or end-destination point.[57] With college campuses, for example, expected to be among initial use case deployments of AV for transit services, the diffusion of similar low-speed AV closed-loop routes as well as first-mile/ last mile applications into rural communities may not be as far behind as some observers anticipate. A key challenge with fully-autonomous vehicles operating in unrestricted environments, including rural environments, is the multiple use cases and scenarios that may need to be considered.[58] As a result, more advanced AV applications could take considerably longer to emerge in rural areas. Research findings from FTA suggest that non-technical issues may present challenges or barriers to the application of advanced automation in transit bus services. Specifically, existing federal safety requirements and test procedures do not anticipate fully driverless AV applications.[59] Were AV transit services for older adults to become viable in rural areas, services would probably still require human operators on board as well as human attendants to assist with entering and exiting vehicles.

Figure 3: Five Levels of Vehicle Autonomy[60]



With fully autonomous vehicles being the automotive industry's research goal, the timing for their market introduction involves a high level of uncertainty given the associated technical risk, as well as faces significant market barriers to their adoption at scale in the form of concerns regarding safety, cost, and liability.[61] Large-scale ITS infrastructure pilots that will support both CV and AV applications are underway nationally. Although most pilot applications are limited to urban centers, pilots in Colorado[62], Ohio[63], and Wyoming[64], for example, are focusing on major transport corridors within those states that hold implications for the broader rural transportation landscape. As the scale of CV implementation grows and capabilities for automation in transportation systems advance, opportunities for vehicle manufacturers, infrastructure providers, innovators, and entrepreneurs to apply related technologies and data towards new and potentially disruptive operational concepts will emerge. The growing availability of data from transportation services will also be an opportunity to apply emerging customer insights on behaviors, preferences, and needs to improve services.[65]

America's *Swiss Cheese* approach to developing a national transportation network suggests that addressing rural transportation needs helps to enhance the whole transportation system, rather than just the holes (where most transportation initiatives and funding are focused).

—Intelligent Transportation Systems Joint Program Office, Department of Transportation[66]

Connectivity is an important enabling technology to realize the potential benefits of CV and AV innovations at scale.[67] The widespread availability of reliable telecommunications infrastructure in rural areas is a significant factor in being able to deliver and furnish access to mobility services.[68] A federally-funded pilot, Transit Tech Ohio, is both upgrading its rural transit systems' hardware and software to allow more than 30 rural transit providers to schedule and dispatch vehicles more efficiently as well as developing broadband infrastructure to guarantee reliable, constant transit base-to-transit vehicle communications. [See Box: Transit Tech Ohio]

Transit Tech Ohio

Ohio Department of Transportation (ODOT) was awarded $6.8M in federal funds through the Transportation Investment Generating Economic Recovery (TIGER) VII competitive grant program to improve rural transit operations for more than 30 rural transit operators as well as expand broadband in underserved areas of OH. The project goals are to provide a minimum set of standards for scheduling and dispatching software, and to eliminate base to vehicle communication gaps by improving broadband access in areas of the state with limited or no broadband connectivity.

Ten counties in southeast OH were identified as having broadband coverage that was insufficient. ODOT found through their community outreach efforts that the more the communities were engaged in the pilot project, the more support the communities provided. Through collaboration with ODOT, local communities willingly provided access to local assets that could be used to install broadband equipment to assist in the facilitation of broadband expansion. The local communities anticipate benefits from the broadband expansion through this pilot project.

The pilot has created a partnership that will broadly benefit the community.

Rural and small metropolitan transportation professionals and their federal and state planning partners anticipate that the transformations currently underway in transportation infrastructure development and related services will influence transportation demand, options and technologies in their communities.[69] There is broad awareness and agreement that CV technology will offer significant opportunities to improve safety outcomes in rural areas and that, longer-term, fully autonomous vehicles might be particularly beneficial to individuals in rural settings with mobility restrictions and where transit services are not available or cannot meet all needs. Transportation professionals and planning partners have also voiced concerns over the regulation and operation of CV and AV in rural settings: Responsibility for designing and maintaining the transportation infrastructure; Safety, including whether technologies will perform appropriately in rural settings; Security and reliability of software; Integration of transportation and telecommunications infrastructure; Mixed technologies and capabilities of vehicles sharing the road during initial implementations; Variation in connected infrastructure implementation; Ownership of data; Employment in commercial driver occupations; Changes in land use patterns and the development local economies due to transportation innovation.[70]

At a regional transportation system level, half of rural roads are unfit for travel and bridges are often structurally deficient.[71] Rural and small metropolitan transportation professionals and federal and state planning partners anticipate improved transportation asset condition management with sensor, software, and drone technologies that improve monitoring and decision support capabilities. Transportation system management and operations organizations are considering deployment of these technologies for rural road safety related to weather conditions, traffic information management services, and traveler information services.[72] [73] For example, organizations can deploy sensor technologies to monitor real-time weather conditions (e.g., wind, snow, ice) and integrate that with probe data (i.e., aggregated, de-identified vehicle location data) to detect anomalies for better situational awareness in the management of traffic systems. At the operational level, drone technology can provide the ability to live-stream video from the scene of a traffic accident, for example, to facilitate fast, efficient assessments in advance of the arrival of emergency services on the scene. In situations where a vehicle may have accidentally gone off road, CV technology could use the relay of GPS signals from the vehicle and/ or its occupants' mobile devices to transmit real-time alerts to passing vehicles.

Improving Access to Transportation

Transit operators have been continually enhancing the way in which they operate and manage transportation assets and systems. In particular, access to real-time transit data is playing a central role in traveler information services, transportation system operations, and travel demand management.[74] The central organizing principle of a shared mobility management model is the process by which service providers work in partnership to manage their transit operations and infrastructure in a coordinated, community-wide transportation service network. The advent of smartphones has been a major driver in the redefinition of transportation in terms of mobility rather than the modes of transportation. This has gradually shifted the primary focus of transportation operators away from the management of service operations to enhancing the experience of personal travel for customers. As a result, the focus of providers has shifted from operational to customer service goals by placing both the transit needs of customers at the center of the transportation design process and coordinating public and private transportation modes available within a defined community in an integrated service model. Transportation network companies, for example, are valued partners when integrated with traditional public transit modes in MOD and MaaS frameworks, with specific benefits as a first mile/ last mile service option.[75]

The application of the MOD framework in rural areas is challenging given that the low densities of dwellings and populations can limit opportunities to create operational efficiencies at scale. The U.S. Department of Transportation recommends leveraging the existing social capital with mobility as one possible means or opportunity to advance MOD applications in rural communities.[76] In particular, a technology-enabled MOD model can improve the traditional grassroots neighbor-helping-neighbor or volunteer models by expanding the variety of resources that can be deployed in unison, improving communication among participants (both within and across communities), and using technology to deliver training to community members. In some rural cases, and particularly among older adults, digital accessibility may prove to be more challenging than transportation accessibility. Innovative solutions that could potentially address current needs and service gaps through the expansion or modification of a MOD model to a rural context could include allowing faith-based mobility subsidies or developing volunteer carpool driver programs.[77] More research is needed to assess the potential use cases for older adults as well as viability and benefits of MOD in rural locations.[78]

ITS technologies effectively address a wide range of stakeholder needs for information, communication and coordination that can assist with the management of integrated transportation resource. ITS technologies can support the data collection required for the coordinated management of transport resources and facilitate the sharing and monitoring of resources in real time.[79] [80] Internet of Things-related applications in devices, vehicles and infrastructure, as a result, facilitate the transmission of real-time automatic vehicle location, speed, and weather condition data that can be used to improve transit operations (e.g., safety, cost efficiency) and customer services (e.g., information services, mobility options). Artificial intelligence capabilities in the form of advanced analytics will be increasingly required given the volume, velocity and variability of data that will be generated. While the operational benefits to users of services do

not require their personal use of Internet of Things-enabled devices, their ability to access real-time information services and make informed choices does. Privacy and security practices are a major concern as are the less well understood aspects of their use.[81]

Use cases of how the Internet of Things through integration with technology-enabled mobility services is driving innovation in transportation for older adults in rural communities include.[82] [See Box: Internet of Things: Improving Access to Transportation]

- **Advancing individual mobility options** through on-demand response services (i.e., Mobility on Demand). Advances related to in-vehicle and wireless communication technologies are transforming the organizational practices of transportation service providers from back-office operational management functions to customer-facing on-demand mobility services. The broad penetration of smartphones has been a major driver in this transformation as has the accompanying growth in consumer expectations for on-demand services.

- **Developing third-party mobility services and apps** through open source software and real-time data exchange standards (i.e., General Transit Feed Specification or GTFS). As communities move toward multimodal, on-demand transportation they are employing open-source initiatives that support interoperable, standardized, and secure data exchange to provide better user travel experiences, as well as exploring ways to display that information to benefit older adults, individuals without smartphones, and persons with disabilities.

- **Improving demand response services** through offering flexible routing and scheduling (i.e., microtransit shuttle services for groups of individual passengers). Through pairing automated vehicle location sensors, for example, with demand response software on the back end and in-vehicle tablet applications on the front end, operators are realizing opportunities to provide more efficient, user-friendly door-to-door demand response services as well as to expand service times and areas.

The Internet of Things: Improving Access to Transportation

VTrans (Vermont)-The recreation of the Uber experience for riders of public transit has been a goal of the Vermont Agency of Transportation (VTrans). The core of its MOD effort was to take OpenTripPlanner, an open-source platform originally developed by Conveyal for TriMet (Portland, Oregon) which provides transit trip plans utilizing GTFS data. VTrans did this through creating a modified version of the GTFS standard (i.e., GTFS-Flex) to incorporate Dial-a-Ride, Hail-and-Ride, and deviated fixed-route services into its trip planner. This development approach has allowed VTrans to

provide improved information to the public, and can accommodate automated vehicle locator (AVL) applications, revealing "real time" on schedules, locations, and routes (i.e., GTFS-RT). Future development goals are for GTFS-Flex data to capture carpools, airport shuttles, taxi cabs, and transportation network companies, and to incorporate real-time demand response trips into the trip planner. It also allows VTrans to avoid the potential risks and costs associated with vendor-lock in, and build an open, modular platform that provides the agency, and other transit providers around the world, with greater flexibility to integrate future developments in the open source development community.

Montachusett Regional Transit Authority (Massachusetts) -The Montachusett Regional Transit Authority (MART) is one of six Regional Transit Authorities contracted with Massachusetts' Executive Office of Health and Human Services (EOHHS) as a transportation broker to manage human service transportation (HST) services for eligible consumers. MART currently accounts for approximately 75 percent of HST trips in the state, and approximately 65% of the expenditures under contract with EOHHS. Its web-based brokerage model has been key in its ability to handle approximately 11,000 Medicaid trips daily. An open-data-exchange platform allows approximately 160 registered providers (private, nonprofit transportation providers; private for-profit providers; private livery services; and taxis) to bid on non-emergency medical transportation trips, review competing bids, and counter-bid. Once bids are closed, MART automatically assigns trips to the lowest bidder, ensuring transparency in pricing and competitive rates. MART is planning to introduce during Q2 2018 an additional scheduling layer for demand-responsive trips. This feature will initially only be available to recipients of a Ride to Wellness grant. The in-vehicle location tracking as well as on-board manifests will provide real-time assessments of location, on-board capacity, and schedule timing to optimize demand-responsive shared ride possibilities.

Via Mobility Services (Colorado)-Via Mobility Services is a non-profit organization that provides on-demand, driver-assisted, door-through-door paratransit transportation services to those facing mobility limitations. Via's primary service area includes Boulder County, with limited service in nearby counties. Via's service deploys demand-response software and in-vehicle tablet devices to provide real-time, automated vehicle location to an open, centralized data exchange. Information about ride availability, location, capacity, rider needs, and real-time vehicle location can be shared to allow providers book rides and coordinate transfers. Via estimates that the technology has enabled it to provide anywhere up to 800 new trips per month. In the future, rather than Via dispatching rides directly to transportation network companies, it envisions the potential for AV as a natural evolution for its business. The service model format will still rely on having human operators on board, together with an attendant or mobility specialist to assist passengers.

Equity, both in terms of technology access and data algorithms, are important considerations for service operators in their being able to apply and leverage the benefits of Internet of Things-enabled services. Moreover, the human-machine

interaction and ethics of big data are critical issues to address in Internet of Things solutions.[83] Transportation-related data in the future could fuse with other Internet of Things data systems that provide contextual data on consumer behaviors in the home to generate automated alerts when anomalies are detected. That alert could be sent directly to notify a medical provider as well as used to simultaneously schedule a medical appointment and door-to-door transportation to the appointment. As these and other developments occur, smartphone and tablet application development, improved demand-response services, open data and software initiatives, and transportation network company programs for first mile/ list mile services will form the essential backbone infrastructure for ensuring customer experience. Transportation providers will have to remain open to constant technological shifts that will require their systems and services remain flexible to adaptation.[84]

Overcoming Barriers to Transportation

Infrastructure investments that expand the availability of high-speed broadband internet and drone delivery services have significant potential to supplement rather than substitute for older adults' transportation needs. For example, broadband availability can contribute to an individual's quality of life through providing social connection (e.g., online social networking platforms and support groups), facilitating the delivery of virtual services to the individual (e.g., telehealth consults through virtual visits for medical care needs), and reducing the need for trips for non-essential goods (e.g., online retail home delivery services). Drone delivery services can ensure the timely delivery of essential, high-value goods (e.g., medical supplies).[85]

Despite rural broadband connectivity continuing to expand geographically, availability in rural areas still lags more densely populated areas. A federal rural broadband investment priority remains those counties dually affected by below national average broadband adoption and above national average chronic disease rates. [See Box: Double Burden Counties: Low Broadband Availability and High Chronic Disease Rates] These digitally isolated counties also experience physician shortages more than double the national average.[86] [87] And where broadband is available, barriers to Internet adoption in rural communities remain significant for individuals with low levels of family income or education. The gaps and obstacles that rural residents face in access can be addressed through greater investment in infrastructure and, once available, subsidies that make services more affordable as well as digital training programs that prepare individuals to realize the benefit from their online participation.

Double Burden Counties: Low Broadband Availability and High Chronic Disease Rates

The majority of rural Americans live in *double burden* counties, with the rural/urban gap holding true even when benchmarks for broadband access are set higher than 60 percent.[88]

- Over 60 percent of rural Americans live in double burden counties; while less than 5 percent of urban America falls into the same category. The rural/urban gap holds true even if the benchmarks are set at 80 -, 70 -, or 60 percent broadband access.
- Rural counties are ten times more likely than urban to be in low broadband access (below 50 percent), high diabetes (above 10%) areas. These digitally isolated counties also experience physician shortages that are more than double the national average.

Telehealth, a technology-enabled model for the delivery of healthcare services that can be either similar in scope or outcome or supplemental to those provided during in-person encounters, holds tremendous potential to facilitate remote access to health services at scale. Two-way live video interaction between a consumer and provider, and the transfer of personal health and medical data from a community setting to a remote provider for monitoring and support as appropriate are two key applications with relevance to older adults and their need for continuity and connectedness with care teams as part of their care management. The Veterans Health Administration, which provides telehealth services as a strategy to prevent the long-term institutionalization of its beneficiaries, provided telehealth visits to more than 702,000 Veterans during fiscal year 2016, with nearly 45% of remote visits involving Veterans living in rural areas. The most common conditions for Veterans using remote patient monitoring were hypertension and diabetes.[89]

Telehealth services will continue to leverage consumer technologies, such as mobile communication platforms, as well as advances in synergistic technology areas such as sensors and data analytics, to expand access to virtual care services that can be delivered both synchronously and a-, remotely, and on demand. In the home setting, Internet of Things-based services will proliferate through the use of wearables and other networked connected health technologies to enable a greater capacity for remote monitoring. As a result, large patient-generated data sets will become available for integration and analysis with health and non-biomedical data for precision medicine applications. The home setting will also benefit from smart connected devices (e.g., Amazon's Alexa) that will serve as hubs to support device connectivity and integrate data flow from devices, as well as serve as personal digital health assistant tools that can provide decision support for healthy behavior change and deliver actionable insights that are customized and predictive in a context aware and lifestyle sensitive manner.

Drones could have an impact on the delivery of consumer goods (on the basis of being quick and convenient) as well as medical goods or emergency medical supplies (on the basis of their high-value relative to the delivery cost) to older adult populations in rural areas. The delivery of standard packages to more remote and difficult to reach areas that make the logistics of human delivery more challenging and resource intensive are also possible.[90] The entry of major retailers (e.g., Amazon), delivery logistics companies (e.g., UPS), and technology leaders (e.g., Google) into this space suggests that significant

resources will be deployed in advancing the commercial potential of the technology. However, the primary application focus remains urban centers, while concerns over safety, logistics, and privacy remain unresolved.[91] A rural health clinic in Appalachia, The Health Wagon, had a successful trial run of a Federal Aviation Administration-approved drone delivery service in 2016. Current guidelines that require that drones not exceed a height of 400 feet and stay within line of sight of operators at all times currently restrict their broad use. Trials are underway to demonstrate efficacy and safety when operating outside of those requirements.[92]

CONCLUSION: CONSIDERATIONS FOR PHILANTHROPY AND INDUSTRY

Information technology plays no small role in the future of transportation, and its role in advancing rural transportation is promising given its potential to improve road safety, improve access to transportation services, as well as provide alternatives to transportation while still meeting individual needs. The rural challenge in that regard is the abundance of scarcity that exists, particularly when it comes to the availability of financial and technical resources, to support the adoption and implementation of technology solutions at scale. During the course of the research, a number of themes emerged with practical relevance to the potential role of technology as a strategy to advance transportation for older adult populations in rural settings:

1. **The rural digital divide is where technology meets rural transportation**-There is a lack of awareness among the technology community of older adults' rural transportation needs, and among rural communities of the opportunities afforded by technology.
2. **There is no one problem, there is no one solution**-Understanding the transportation solution for older adults in rural communities requires first identifying what is important to the individual user and assessing local resources and partners to meet those needs.
3. **Greater transportation diversity builds resilience**– The greater the options in modes available and that an individual has available to address their personal travel needs, the greater the potential resiliency of the community transportation network.
4. **Each community has unique needs and resources to address needs**-A recommended approach is to first leverage the resources, supports and infrastructures that already exist within communities before introducing a new solution to an old problem.
5. **Stakeholder partnerships are often key strategies for success**-Successful strategies are built on community-wide coalitions that have a shared goal, can pool resources, and have the ability to assess the transportation issue from different perspectives.
6. **Access to transportation is a social determinant of rural health**-Access to transportation not only impacts health status but also quality of life due to the ability for older adults to engage and participate fully in community life.

7. **Equitable access for rural populations is a basic right**-The ability of rural populations to have equitable access to not only transportation but also to technology and participation in civic activities benefits both the individual and the community.
8. **Blended transportation solutions for all are potentially more sustainable**-Services that are a shared community resource and that all community members can benefit from are potentially more sustainable than more specialized services.
9. **Smartphone technology has been a driver in redefining transportation services**–The high level of personal smartphone penetration has enabled transportation providers to advance user-centered service models and prioritize individual user travel experiences.
10. **People want to be able to lead spontaneous lives**-Frameworks that prioritize individual mobility preferences and needs and coordinate different service options available to match preferences and meet needs are the emerging trend across aging services.
11. **Balance the use of technology with human-centered, high-touch strategies**-A technology-enabled service model that incorporates human support reflects a design strategy that meets older adults' preferences when using technology-enabled services.
12. **Transportation is expensive and will never be free**-Social entrepreneurship is a potential innovation model to effectively address the transportation needs of older adults while also providing economic and social benefits for rural communities.

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GLOSSARY OF KEY TRANSPORTATION AND TECHNICAL TERMS

Artificial Intelligence: A branch of computer science dealing with the simulation of intelligent behavior that is learned, displayed, and carried out by machines, in contrast to the natural intelligence displayed by humans and other animals.

Autonomous Vehicle: A vehicle that is capable of sensing its environment and navigating with varying levels of direct human driver input to control key operational functions such as steering, acceleration, and braking.

Connected Vehicle: A vehicle that is equipped with wireless communication capabilities to enable the transmission and receipt of data with other vehicles on the road (vehicle-to-vehicle) and roadside infrastructure (vehicle-to-infrastructure).

Demand Response Service: A transit service that does not follow a fixed route but where individual passengers can request transportation from a specific location to another at a certain time. It often requires advance registration.

Drone: An unmanned airborne vehicle that may be remotely controlled or fly autonomously through software-controlled flight plans working in conjunction with onboard sensors and global positioning systems.

Fixed Route Service: A form of public transportation that can be operated by both public and private entities to transport individuals on designated routes with fixed stops and according to a fixed schedule or timetable.

Intelligent Transportation System: A framework within which different modes of transport and traffic management systems can exchange data and operate together to relieve congestion, improve safety, and manage transportation networks.

Internet of Things: An interconnected network of everyday physical devices, including vehicles, that are embedded with electronics, sensors, software and Internet connectivity to enable machine-to-machine communications.

Machine Learning: A subset of artificial intelligence that uses statistical techniques to give computer systems the ability to *learn* with data, and thereby progressively improve performance on a specific task, without being explicitly programmed to do so.

Microtransit: A private multi-passenger transportation service that provides a transit-like service but on a smaller, more flexible scale using dynamically generated routes, and that may expect passengers to make their way to and from common pick-up or drop-off points.

Mobility-as-a-Service: The integration of various forms of transport services that are accessible through the use of a single application to provide on-demand access to mobility services with a single payment channel.

Mobility on Demand: An integrated and connected multi-modal network of shared mobility, goods delivery, and public transit service solution that are available and accessible to all travelers.

Mobility Management: A system-level, customer-centered approach to designing and delivering mobility services through providing information and referrals to assist individuals in learning about and accessing community and regional transportation services.

Ridesharing: A service that offers the ability to add passengers to a trip through matching drivers and passengers who share a common destination. Traditional forms of ridesharing include carpooling and vanpooling.

Ride-hailing: An on-demand mobility service that uses online platforms to connect passengers with a variety of service classes, and that automates reservations, payments, and customer feedback.

Telehealth: The use of information and telecommunications technologies for facilitating the delivery of healthcare, public health, and health education services at a distance and across a variety of settings.

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