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OLDER ADULTS, NEW MOBILITY, AND AUTOMATED VEHICLES

LAURA FRAADE-BLANAR, NICO LARCO, RYAN BEST, TIFFANY SWIFT, MARJORY S. BLUMENTHAL

URBANISM NEXT CENTER

UNIVERSITY OF OREGON

RAND CORPORATION

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The *Older Adults, New Mobility and Automated Vehicles* report is a collaborative effort between AARP Public Policy Institute, RAND Corporation, the Urbanism Next Center at the University of Oregon, and various subject matter experts which discusses the key factors relating to mobility of older adults and emerging mobility options.

Project Manager:

Jana Lynott	AARP Public Policy Institute

This report was written by:

Laura Fraade-Blanar	RAND Corporation
Nico Larco, AIA	Urbanism Next/UO
Ryan Best	RAND Corporation
Tiffany Swift	Urbanism Next/UO
Marjory S. Blumenthal	RAND Corporation

Graphic design by:

Tristan Govreau	Urbanism Next/UO
Matthew Stoll	Urbanism Next/UO

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URBANISM NEXT CENTER

The Urbanism Next Center at the University of Oregon conducts research and convenes partners from around the world to understand the impacts of new mobility, e-commerce and urban delivery, and autonomous vehicles on the built environment. Going beyond these emerging technologies, we explore the possible implications on equity, health and safety, the economy, and the environment to inform decision-making that supports community goals. Urbanism Next brings together experts from a wide range of disciplines including planning, design, development, business, and law and works with the public, private, and academic sectors to help create positive outcomes from the impending changes and challenges confronting our cities. Learn more at www.urbanismnext.org.

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Their affiliations include:

AARP; Agile City Partners; City of Detroit, Office of Mobility Innovation; Contra Costa Transit Authority; Ford Mobility; Full Path; Insurance Institute for Highway Safety; Massachusetts Institute of Technology, AgeLab; Michigan Department of Transportation; MoGo; National Institute on Aging, Division of Behavioral and Social Research; San Francisco Municipal Transportation Agency; The Robotics Institute at Carnegie Mellon University; Toyota, Collaborative Safety Research Center; Uber; U.S. Department of Labor; U.S. Federal Transit Administration; University of Florida, Department of Occupational Therapy; University of Texas at Arlington, Department of Civil Engineering; Via; Voyage; and Waymo.

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FOREWORD

The premise that autonomous vehicles will address older adults' immobility is not a given. As argued in the Public Policy Institute's publication Universal Mobility-as-a-Service, public- and private-sector actors need to come together to create a set of supportive circumstances that enable us to harness emerging technology for individual and societal benefit.

This paper and associated framework lays out the myriad and interconnected factors that all stakeholders in this space should be thinking about so that the promise of autonomous vehicles and new shared-use mobility opportunities can be realized. The framework can be used as a checklist of design considerations for AV pilot testing, and it also may inform research and development programs. Moreover, it can provide an easy-to-consult reference for policymakers as they define roles and responsibilities among public- and private-sector actors whose actions can enable equitable access—or result in greater *in*equity.

This research reveals a perennial flaw in our technology adoption process, at least in the mobility arena: the current default of designing for a broad clientele of mobile individuals is insufficient. The framework identified in this report is an important but only preliminary step to ensuring that the needs of harder-to-serve populations, such as frail older adults and people with mobility disabilities, are met. Additional, more tailored activity is needed. AARP looks forward to advancing this work.

Jana Lynott
Project Manager
Senior Strategic Policy Advisor
AARP Public Policy Institute

SUMMARY

Mobility is a life necessity, enabling functions ranging from going to work, to purchasing food, to going to doctors' appointments. Unfortunately, many older adults have comparatively fewer transportation options than their younger counterparts. Even as that perennial problem persists, the transportation landscape is rapidly shifting. The introduction of shared-use mobility, such as carsharing, ridehailing, bikesharing, and shared e-scooters, offer new options and potential solutions. Related to these shifts are the automated vehicle (AV) and related technologies.

These innovations may expand the transportation options available to older adults, but their deployment is proceeding in a context where the safety, accessibility, affordability, equity, and livability effects on older adults are not well understood. In starting to define that knowledge gap, we conducted preliminary research on the potential benefits and harms to older adults that arise from the introduction of AVs into an already emerging transportation ecosystem that includes new shared mobility options and Mobility as a Service (MaaS). Our methods included a review of the available literature, interviews with subject matter experts, and convening a roundtable that included policymakers, technologists, private sector transportation companies, and other researchers.

From our research we developed a framework of key factors relating to mobility for older adults that is presented in this paper. The framework is intended to guide planning for new mobility and AVs, and ensure older adults' needs are considered and met. While our focus is older adults, we recognize the importance of universal design – which aims to support all potential users – and so the factors identified and discussed in the framework could benefit anyone, not just older adults. Indeed, the potential to benefit many populations might broaden the base of support for corresponding actions.

The subject matter experts we engaged agreed with the issues represented in the framework as well as with the need for such a framework. A lack of consensus on who (federal, state, local governments, private sector companies, and/or advocacy groups) should be responsible for addressing the issues represented in the framework is worrisome. Policy development and a conscious effort to drive beneficial outcomes are reliant on addressing the appropriate roles for the public and private sectors. Moreover, our research found limited attention being given to addressing the needs of hardest-to-serve older adults and people with disabilities—those with limitations (physical, cognitive, multiple disabilities, financial, technology access/understanding) or certain specific needs (transportation that accommodates mobility aids, low-income, rural location). These populations could see an overall *reduction* of transportation options due to the possible impacts of AVs and new shared mobility on public transportation. Our findings point toward several ideas for next steps that can help ensure improvements to older adult mobility.


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INTRODUCTION

The transportation landscape is beginning to witness a potentially dramatic shift as new transportation models and technologies enter the marketplace. While these innovations are often touted for how they might expand mobility options, their impacts on public transportation, their cost, and their focus on able-bodied and able-minded users could inadvertently reshape transportation options in ways that will limit mobility for many older adults. The stakes are clearly high. This report and its appendices are meant to serve as a guide for framing key issues around new mobility, AVs, and older adults so policymakers, advocates, and researchers can have an informed view of the decisions before them and can better understand areas in need of further investigation.

Transportation is a fundamental need that does not decrease with age, driving ability, or changes in physical or cognitive state. Access to transportation, especially driving, confers benefits including the promotion of general life satisfaction.[1] Access is one of the key social determinants of health, and the lack of access is associated with challenges for caregivers and negative health outcomes, including social isolation, depression, and early entry into a long-term care facility.[2,3]

1 Chihuri, S, Mielenz, T. J., DiMaggio, C. J., Betz, M. E., DiGuiseppi, C., Jones, V. C., & Li, G. (2016). Driving cessation and health outcomes in older adults. Journal of the American Geriatrics Society, 64, 332-341.

Harrison, A., & Ragland, D. (2003). Consequences of driving reduction and cessation for older adults. Transportation Research Record, 1843, 96-104.

2 Breen DA, Breen DP, Moore JW, Breen PA, O'Neill D. Driving and dementia. Br Med J. 2007;334(7608):1365-1369.

Martin A, Marottoli R, O'Neill D. Driving assessment for maintaining mobility and safety in drivers with dementia (review). Cochrane Database Syst Rev. 2011;(10).

AGS/NHTSA. Clinician's Guide to Assessing and Counseling Older Driver. 3rd ed. (American Geriatrics Society, Pomidor A, eds.). Washington, DC; 2016.

Freeman EE, Gange SJ, Munoz B, West SK. Driving status and risk of entry into long-term care in older adults. Am J Public Health. 2006;96(7):1254-1259.

Brown L, Ott B. Prediction of on-road driving performance in patients with early Alzheimer's Disease. J Am Geriatr Soc. 2005;53(1):94-98.

3 https://www.aha.org/social-determinants-health/populationcommunity-health/community-partnerships

A host of mobility options have emerged in recent years. These include ridehail services such as Lyft and Uber, microtransit including I.T.-enabled vans and shuttle-bus pickups, carshare businesses like Zipcar, and micromobility options such as bikesharing and shared e-scooters. At the same time, early research suggests that commercially available advanced driver assistance system technology in cars can extend an older adult's driving years. Automated vehicles (AVs) are a natural extension of driver-assistance technology. Their impacts, however, on safety, accessibility, affordability, equity, and livability[4] for older adults are not well understood. The efficacy of AV technology will hinge on specific vehicle capabilities, cost, accessibility features, and rollout decisions. Failing to accommodate older adults in the rollout of AVs would be a missed opportunity for a large and growing segment of the population.[5] Not only could AVs have the adverse effect of substantially decreasing the overall mobility options of older adults, but such an outcome would leave vehicle producers unable to fully tap a large—and lucrative—market.

We identify factors that will affect how older adults experience AVs, and new mobility more generally, in this brief report. Additionally, we explore possible unintended consequences of AVs for older adults, especially for those individuals that are harder to serve, along with responsibilities for ensuring older adult access to AVs. We focus on what are known as Level 4 AVs, self-driving vehicles that require no human supervision as long as specific conditions are met.[6]

PROJECT METHODOLOGY

Our exploration drew from previous research by Urbanism Next and RAND on the impacts of new shared mobility and AVs on transportation access, a non-systematic review of relevant literature (outlined in Appendix 3), interviews with a purposeful sample of subject matter experts whose affiliations are listed at the end of this summary (in Appendix 1), and a roundtable discussion with a mix of experts identified through our research or our professional networks. The roundtable was held on September 23, 2020 with 28 participants.

This report also aims to frame future work and research around these topics. In order to provide a brief and readable overview, more detail can be found in the appendices (see Project Methodology box for an overview of our methodology). The lively interaction among people with different backgrounds during our project roundtable provided feedback on our early formulation of a conceptual framework. The enthusiastic reaction validated our belief that this kind of framework can be helpful to the variety of stakeholders interested in improving transportation for older adults, and can inform future AV initiatives and research.

4 Livability has been defined broadly in different contexts, but in this case refers to a community's overall ability to provide choices for transportation, housing, and other community features that support physical and emotional needs of residents.

5 As the last of the baby boom cohort reaches retirement age, it is projected that 1 in every 5 Americans will be 65 or older by 2030 [Older people projected to outnumber children for first time in US history. US Census Bureau, March 13, 2018. https://www.census.gov/newsroom/press-releases/2018/cb18-41-population-projections.html].

6 https://www.sae.org/news/press-room/2018/12/sae-international-releases-updated-visual-chart-for-its-%E2%80%9Clevels-of-driving-automation%E2%80%9D-standard-for-self-driving-vehicles

CLUES FROM EARLY FORMS OF NEW MOBILITY—A GLIMPSE OF TOMORROW, TODAY

While AVs remain under development and testing, we can use the current ridehailing service model as a proxy for a fleet-based AV future to help consider potential implications for older adults. Although ridehailing relies on human drivers, it involves a business model that presents a similar consumer experience to what is expected for AVs. In both ridehailing and anticipated AV services, a rider requests a vehicle, often by using a smartphone app, has the vehicle come find them, enters, rides to a predefined destination, exits, and pays electronically for the service. While the similarities between ridehail and fleet-models of AV deployment are clear, the field of research on automated vehicles and their societal impact is in its infancy. Due to the absence of available studies, particularly those using AVs without a safety driver present, the similarities between AVs and ridehail cannot be statistically established. Though direct research is currently unavailable, the conceptual similarities between the two transportation models allow us to study the benefits, challenges, and equity barriers of existing services as a proxy to better understand future AV services.

Existing services also illuminate the evolution of Mobility as a Service (MaaS).[a] MaaS allows travelers to find trip routing information, book rides, and pay for trips all in a single app.[b] MaaS apps can include both fixed-route and on-demand shared transportation services across a wide variety of modes. In its fullest implementations, MaaS can facilitate mobility for many.[c] Although there is high interest in the growth of MaaS, to date, there has been limited deployment and MaaS systems are in their infancy.[d]

a Transportation experts sometimes speak of mobility as a service broadly, including technology-based integration of different modes of transportation supporting complete, door-to-door trips.

b One source of information on MaaS is the Shared-Use Mobility Center. See: https://sharedusemobilitycenter.org/

c Lynott, Jana, Universal Mobility as a Service: A Bold Vision for Harnessing the Opportunity of Disruption, AARP Public Policy Institute, September 2018.

d Zipper, David, The Problem With 'Mobility as a Service', CityLab, August 5, 2020, https://www.bloomberg.com/news/articles/2020-08-05/the-struggle-to-make-mobility-as-a-service-make-money?sref=LOxEm0mA.

EXISTING BARRIERS

Existing models of new mobility and early deployment of AVs are already pointing to potential barriers for older adults—as well as potential improvements (see box entitled, "Clues From Early Forms of New Mobility—A Glimpse of Tomorrow, Today"). Using these emerging transportation technologies requires a base level of tech fluency, smartphone and internet access, and access to making online payments. Some older adults are uncomfortable with using technology,[7] and as of 2019, only slightly more than half of adults ages 65 and older in the U.S. own a smartphone.[8] Further, nearly half of the people in a recent U.S.-based transportation study reported being uncomfortable with online payments.[9] Beyond discomfort with technology, older adults often face physical barriers to using new mobility services. The vehicles can be difficult to enter and exit, and they may not easily accommodate the walking aids or wheelchairs that are used by approximately a quarter of all older adults.[10]

Although many older adults need door-to-door or hand-to-hand service,[11] current and projected offerings focus almost exclusively on curb-to-curb service. AV services may also pose a challenge for older adults if there is no one available to adequately guide them during partial or complete equipment or service breakdowns. These challenges may lead older adults to have to travel with a family member or other caregiver, another factor in diminishing mobility.

As all of these factors surrounding the use of new mobility and AVs are relevant to the greater public, and not just to older adults, there is benefit in adopting a "universal design" approach. This approach focuses on the design of products and systems to promote use by all people, including those with physical and cognitive limitations due to impairments or circumstance.[12] If universal design is applied to the task of designing AVs and their service deployment in ways that promotes their use by older adults, by definition, users of any age would benefit.

Our exploration put a spotlight on the subset of older adults that are hardest to serve. We use the term hardest/harder-to-serve to refer to those with the fewest convenient transportation options (due to, for example, living in rural areas), people with the most limited resources for getting extra or tailored services (because they have low levels of income or technology literacy), and, in particular, those whose abilities are the most limited such as those with cognitive and/or physical impairment. Even with conventional transportation, some people are harder to serve.

7 Lee, C. C., Czaja, S. J., Moxley, J. H., Sharit, J., Boot, W. R., Charness, N., & Rogers, W. A. (2019). Attitudes toward computers across adulthood from 1994 to 2013. The Gerontologist, 59(1), 22-33.

8 Anderson, M. (June, 2019). Mobile technology and home broadband, 2019. Pew Research Center, Washington, D.C. https://www.pewresearch.org/Internet/2019/06/13/mobile-technology-and-home-broadband-2019/

9 Golub, A., Brown, A., Brakewood, C., and J. MacArthur (2020) Applying an Equity Lens to Automated Payment Solutions for Public Transportation. National Institute for Transportation and Communities (NITC). https://nitc.trec.pdx.edu/research/project/1268

10 Gell, N. M., Wallace, R. B., LaCroix, A. Z., Mroz, T. M., & Patel, K. V. (2015). Mobility Device Use in Older Adults and Incidence of Falls and Worry About Falling: Findings from the 2011–2012 National Health and Aging Trends Study. Journal of the American Geriatrics Society, 63(5), 853–859. https://doi.org/10.1111/jgs.13393

11 Fraade-Blanar, L and Whaley, C. Non-Emergency Medical Transportation and Rideshare. In Review. RAND 2020.

12 Story, M. F. (2001). The principles of Universal Design. In F. E. W. Preiser & E. Ostroff (Eds.) Universal Design Handbook, 2nd ed. (pp. 4.3-4.12)

Older adults who use wheelchairs and other assistive technologies may not be served well, or at all, by today's forms of new mobility. Rarely are adaptive scooters and bikes made publicly available, and too often micromobility devices are left blocking sidewalks. These devices can limit older adult mobility by creating tripping hazards or effectively making the pedestrian path too narrow to navigate using mobility aids or wheelchairs. Moreover, very few privately owned ridehailing vehicles are wheelchair accessible. AVs might repeat that experience to the detriment of older adults and others depending on assistive technologies. Of particular concern for mobility services that depend on use of wireless communication, many rural areas have spotty or nonexistent wireless coverage—and in the United States, 10.6 million older adults live in rural areas.[13,14]

With foresight and planning, undesirable outcomes can be avoided so that the opportunity presented by the new technology can be realized. If universal design is applied to the task of designing AVs and their service deployment in ways that promotes their use by older adults, by definition, users of any age would benefit.

OLDER ADULTS, NEW MOBILITY AND AVS – A FRAMEWORK

The framework developed through this project (Figure 1) describes the array of new mobility and AV-related factors that determine and drive older adult mobility. These factors and their interaction are outlined below and elaborated in Appendix 2. The structure and content of this framework draw from two models developed in the research community. The first model[15] emphasizes the multiple layers of influence that determine behavior, and it recognizes that behavior shapes and is shaped by the physical and social environment. This model explores how factors in one layer influence factors in others. Layers progress from the individual to the societal.[16] These nested layers make explicit that factors facilitating or hindering older-adult transportation are not determined by one entity. Efforts to advance and enhance older adult transportation opportunities must work on multiple levels. The second model[17] considers influential personal, physical, and political factors in all stages of a trip, a motor vehicle crash or injury, or any other type of public health event.[18] Just as the first or socio-ecological model explores levels of influence, the second or Haddon Matrix model identifies factors within the framework. A detailed explanation of framework factors and levels resides in Appendix 2. Appendices 2 and 3 also show how research and other literature support the framework.

13 Kane, T., Borghei, B.A., Darr, B., Hild, R., Kaczmarek, K., and Lewellen, M. Rural America:How Wireless Technologies Could Impact America's Heartland https://wia.org/wp-content/uploads/WIA_RuralAmerica-2.pdf

14 Symens Smith, Amy and Trevelyan, Edward. In Some States, More Than Half of Older Residents Live In Rural Areas. Census.gov, October 22, 2019. https://www.census.gov/library/stories/2019/10/older-population-in-rural-america.html

15 The socio-ecological model, which was created in the 1970s to explore human development https://www.tandfonline.com/doi/full/10.1080/1059924X.2017.1358971

16 https://www.cdc.gov/violenceprevention/publichealthissue/social-ecologicalmodel.html
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.458.7039&rep=rep1&type=pdf
https://www.safestates.org/page/SRPFSEM

17 This model is the Haddon Matrix, created by William Haddon, Jr., the first administrator of the National Highway Traffic Safety Administration.

18 https://safety.fhwa.dot.gov/hsip/resources/fhwasa09029/app_c.cfm
https://injuryprevention.bmj.com/content/4/4/302

The framework provides an initial tool for identifying what to pay attention to and what is at stake as decisions are made about AV design and associated public policy. Individual factors draw attention to potential barriers that may be experienced by older users (and others facing similar circumstances). The higher-order factors shown in the far left column of Figure 1 provide important first steps in organizing the individual factors by their role in the complete trip and also where interventions might be focused. In relation to the harder-to-serve older adult populations, the most salient areas of the framework are within the demand-side factors and supply-side access factors. While all factors are critical to ensure equitable access to AVs and new mobility, the demand-side factors and supply-side access factors include many of the most challenging barriers for older adults and topics where roles and responsibilities are unclear. For example, who is responsible for ensuring older adults have access to and knowledge of smartphones, as well as mobile data coverage needed to use new mobility services and eventually AVs? How do public, private, and non-profit entities ensure that rural older adults, who already have limited non-driving transportation options, are not further left behind by new mobility services concentrating in urban areas?

Physical and social environment factors affect older adults differently, and they have not been adequately taken into account during the rollout of new mobility. For instance, on-street parking dedicated to personal cars may result in ridehailing vehicles being unable to approach the curb where they can safely enable those with mobility limitations to enter and exit the vehicle. Moreover, ridehailing service itself could inadvertently undermine other travel options. The popularity of ridehailing has reduced public transportation ridership.[19] This could undercut an important source of revenue and political capital for transit routes and paratransit service and potentially present access barriers for low-income travelers, those who cannot walk long distances to a bus stop, and those who depend on paratransit.

By including factors across overlapping spheres of influence, the framework highlights the many disparate prerequisites needed for AVs to truly expand mobility for older adults. The framework's organization serves as a foundation from which to base future discussions on the roles and responsibilities of stakeholders when addressing these issues. Since it cannot be assumed that AVs will solve all mobility problems of older adults (and others who are harder to serve), the framework provides a tool for identifying what to pay attention to and what is at stake as decisions are made about AV design and associated public policy.

19 Graehler, Mucci and Erhardt, 2019; Schaller, 2018; Shaheen and Chan, 2016.

FIGURE 1: A FRAMEWORK FOR OLDER ADULT MOBILITY FACTORS

INDIVIDUAL LEVEL

DEMAND-SIDE FACTORS

SMARTPHONE ACCESS
Smartphone ownership among older adults as an enabler for accessing rides in a ridehailing or MaaS model

SMARTPHONE USE
Familiarity and use of app and smartphone technology

ACCESS TO ONLINE PAYMENT
Access to and familiarity and comfort with online banking systems and/or payments

AFFORDABILITY OF SERVICES
Amount and kind of mobility options that older adults can afford

BARRIERS OF TRUST AND ATTITUDE TOWARDS TECHNOLOGY
Attitudes, acceptance, and trust of mobility technologies, notably AVs

PHYSICAL BARRIERS
Barriers entering and exiting the transportation vehicle, and barriers to traveling to and from transportation (e.g., "the last 10-meter issue")

LANGUAGE BARRIERS
Communication barriers between riders and drivers, apps, on-board interfaces, etc.

COGNITIVE BARRIERS
Abilities to comprehend and respond to cognitive requirements associated with travel

SAFETY FACTORS (INDIVIDUAL)

NON-CRASH-RELATED HEALTH FACTORS
Injuries or other health problems incurred while entering, exiting, or using the vehicle

PERSONAL SECURITY CONCERNS
Issues with sharing a transportation environment with drivers or with other passengers (e.g., concerns over aggression, needing assistance)

ORGANIZATIONAL LEVEL

SAFETY FACTORS (ORGANIZATIONAL)

CRASH PREVENTION
Increases or decreases in the likelihood of a crash

VEHICLE OCCUPANT OR PEDESTRIAN SAFETY
Protecting (or failing to protect) individuals from harm in the event of a crash

SUPPLY-SIDE ACCESS FACTORS

ACCOMMODATION OF GOODS OR AIDS
Accommodation of travelers' paraphernalia, including goods, groceries, suitcase, walkers, or wheelchairs for the mobility-impaired

TRAVEL OPTIONS FIT WITH USER NEEDS
Alignment of transportation options with the diverse trip needs (traveling long distances, for a medical emergency, to a rural destination, etc.)

TRAVEL OPTIONS FIT WITH ENVIRONMENTAL CONDITIONS
Alignment of transportation options with current environmental factors (e.g., weather, extreme traffic patterns, natural disasters, etc.)

AVAILABILITY OF TRANSPORTATION SERVICES IN YOUR AREA
Availability (or lack of availability) associated with urban/suburban/rural location and/or economics of service deployment

CONSISTENT TRANSPORTATION SERVICE AVAILABILITY
Regularity, frequency, and reliability of access to transportation options/services

BIAS IN AVAILABILITY
Racial, economic, ability, or other biases shaping what kinds of transportation are available, where, when, and at what price

SOCIETAL LEVEL

LAND USE & TRANSPORTATION PLANNING FACTORS

CURB AND SIDEWALK MANAGEMENT POLICY
Proximity and accessibility of the pickup/drop off location for older adults

STREET CROSS-SECTION DESIGN
Support (or lack of support) for older adult mobility needs (pick up/drop off areas, safe pedestrian crossing, etc.) through design and use of the street and sidewalk space

TRANSPORTATION SYSTEM FACTORS

AVAILABILITY OF PUBLIC TRANSPORTATION OPTIONS
Increase or reduction in availability of affordable or accessible public transit services that older adults rely on

AVAILABILITY OF LAST-MILE OPTIONS
Increase or reduction in availability of affordable or accessible last/mile or door-to-door services that older adults rely on

SECONDARY RESPONSE FACTORS

OTHER IMPACTS OF NEW MOBILITY/AVS ON TRANSPORTATION SYSTEM
Changes in the transportation system that affect older adult mobility beyond availability, affordability, and accessibility

USING THE FRAMEWORK

The framework is a tool that organizes and highlights the breadth of factors related to older adults' adoption of, access to, and ability to use new mobility and AVs. It reveals the possible unintended consequences of new mobility and AV deployment, and it also illuminates paths for interdisciplinary collaboration to equitably serve older adults. With many governmental, non-profit, and private sector organizations involved, the framework can be used to guide a wide range of activities. Our roundtable participants described the strong need and utility of this type of framework. City and state government officials might use the framework as a checklist when planning new mobility pilots for older adults, or as an evaluation tool post-pilot. Private sector partners, such as vehicle producers or new mobility service companies, might use the framework to expand their research agenda,[20] and explore adjustments to their products, services, communications and partnerships. Travel trainers, who educate older adults in mobility options, might use the framework to customize their curriculum to better address new mobility, and eventually AV services.[21]

While the framework is presented in a flat diagram, factors are not independent. Many—if not all—of the factors are intertwined. Policy influences organizational-level factors, which affect individual-level factors. For example, policy can shape sidewalk design and the use of that public space, which affects the access for individuals with mobility aids, and in turn affects emotions and attitudes related to the service.[22] Likewise, the relationship between supply- and demand-side factors is not unidirectional. Older adults seek to use the options that are available.

Stakeholders should use the framework to improve the rollout of new mobility technologies by shaping the evolution of the technology. Waiting for the technology to mature and then adapting it to older adult needs may mean it is too late to make significant and impactful changes. This leaves the needs of older adults at risk of being overlooked. While potential travelers must know what services are available to want to use them, and AV and new mobility producers have to be confident that they can sell a capability before making it available, stakeholders concerned about the adequacy of transportation for older adults should be at the table prior to market introduction. Based on the lessons from the rollout of other new mobility technologies, such as the recent proliferation of e-scooters in some cities,[23] it is not too early to elevate the needs of older adults related to AV design. By being involved now in conversations about AV policy and services stakeholders can forge the structures and collaborations needed to tackle the complex factors articulated in the framework.

TWO KEY STRUCTURAL BARRIERS

In addition to issues delineated in the framework, our interviews and roundtable discussion pointed toward two barriers that currently limit how the public and private sectors address older adult issues in new mobility and AV deployment.

20 One AV developer flagged that value during our roundtable.

21 One researcher proposed this use during our roundtable.

22 Topic raised during roundtable discussion.

23 In failing to preemptively identify and adequately address the impact of dockless e-scooters on older adults we found them scattered on sidewalks, blocking wheelchair access.

Discussed below, they are (1) the lack of attention to harder-to-serve populations and (2) uncertainty about different stakeholders' roles and responsibilities in ensuring older adults' access to and benefits from new mobility and AVs.

KEY CHALLENGE: HARDER-TO-SERVE OLDER ADULTS

Existing new mobility options, and by extension the eventual introduction of AVs, primarily cater to the easiest to serve older adult (and other) populations. Due to profitability and liability pressures, new mobility companies have focused on an older adult population that is similar to their broader clientele in terms of physical mobility, cognitive and physical fitness, financial resources, and technology comfort and fluency.[24] While these segments of the older adult population might have reduced or ceased driving themselves, they have begun to adopt new mobility options such as ridehailing services. New mobility companies are experimenting with ways to expand this adoption – offering other transportation options for those who often already have many.

The situation has left a large population of harder-to-serve older adults outside of the new mobility revolution, largely unable to access its benefits. Those who have more limitations (physical, cognitive, multiple disabilities, financial, technology access/understanding) or certain specific needs (transportation that accommodates mobility aids, low-income, rural location) often do not fit into current new mobility business models. This cohort was acknowledged in our stakeholder conversations as unfortunately being "nobody's problem." They tend to rely primarily on friends, family, caregivers and social service transportation options that can be lacking in reliability, efficiency, or coverage.[25] These older adults represent a pent-up demand for affordable, on-demand, and accessible transportation to health care, errands, and social activities,[26] but face a future with potentially limited mobility options.

Advanced age into older adulthood is associated with a reduction in trips taken on a given day, particularly in the percentage of individuals that do not travel at all. In a 2017 National Household Travel Survey, 25.3 percent of adults aged 65+ reported not taking a trip in a given day, compared with 15.5 percent in the younger age groups. This increased with higher age cohorts, with 28.8 percent of those aged 70+ and 32.9 percent in individuals aged 75+ reporting no trips. When asked to provide a reason why they did not take a trip in a given day, older adults were much more likely to report it was due to disability or being homebound (17 percent aged 65+, 20.3 percent aged 70+, 24.2 percent aged 75+) compared to younger age groups (5.3 percent aged 5 to 64). Older adults living in urban areas were slightly more likely to report that they did not take a trip due to disability or being homebound (18.1 percent aged 65+, 21.4 percent aged 70+, 25.5 percent aged 75+) when compared to older adults living in rural areas (13.4 percent aged 65+, 16.5 percent aged 70+, 20.1 percent aged 75+).[27]

24 Topic discussed during subject matter expert interviews

25 https://www.nadtc.org/wp-content/uploads/KRC-nadtc-Survey-Report-120718-FINAL_for-web508.pdf

26 Saxon, L., Ebert, R., & Sobhani, M. (2019). Health impacts of unlimited access to networked transportation in older adults. The Journal of mHealth. https://thejournalofmhealth.com/health-impacts-of-unlimited-access-to-networked-transportation-in-older-adults/

27 Data points in this paragraph are based on analyses of the 2017 National Household Travel Survey by the AARP Public Policy Institute.

Disability and other limitations can serve as barriers for transportation at multiple points throughout the trip. The harder-to-serve older adult populations have particular challenges in the pre- and post-ride portions of a trip.[28] Currently, new mobility companies focus on the curb-to-curb experience, but many in this population require door-to-door or hand-to-hand service. Subject area experts in our roundtable and interviews cited challenges for this population such as:

- Identifying the vehicle if one does not have a smartphone;
- Orienting oneself when dropped off;
- Getting to a curb cut if using a walker or wheelchair;
- Stowing bags or mobility aids;
- Safely getting out of or into the vehicle, especially where there are approaching vehicles/bicycles; and,
- Finding the front door or correct door at a more complex location, such as a hospital or shopping center

Addressing the door-to-curb portions of trips will require interdisciplinary solutions from healthcare providers, mobility companies, and social service organizations, with a hybrid of person-to-person education and technology solutions, all of which carry costs, are sometimes cumbersome, and often time-consuming.

Eliminating the "nobody's problem" challenge will require public and private sector focus, funding, and coordination between traditional paratransit providers (local governments, social service organizations), microtransit, existing new mobility providers, and eventually AV companies. That coordination requires bridging a digital divide between these different kinds of transportation suppliers. Stakeholders we interviewed were clear that this coordination and focus on harder-to-serve older adults are not happening organically today, although there have been some pilot projects focused on older adults that have sought to address some of these barriers, such as cost and technology access (see Appendix 3).

ROLES AND RESPONSIBILITIES

While the experts we engaged agreed with the topics in the proposed framework, there was a lack of consensus on which stakeholders should be responsible for identifying and/or implementing solutions to those issues. This was especially true with respect to those who are harder to serve. Some stakeholders had conflicting views, while others were simply uncertain about who should be taking leading roles on specific issues. This was true both in terms of the roles of local, state, and federal governments and for how responsibility should be shared among public sector, private sector, and advocacy organizations.

28 Coughlin, J. (November, 2017). Why driverless cars alone will not solve transportation in older age. Forbes. https://www.forbes.com/sites/josephcoughlin/2017/11/30/why-driverless-cars-alone-will-not-solve-transportation-in-older-age/#7fdbffe797ae

While this research was not focused on roles and responsibilities, the lack of clarity on them was discussed during the roundtable session as an impediment to equitable access to new mobility options for older adults. Unclear roles and responsibilities can lead to a patchwork approach to policy, a situation that risks having issues fall through the cracks.[29]

29 RAND's body of research on policy related to AVs has documented the challenges of policy patchworks in that arena generally.

NEXT STEPS/FUTURE WORK

The proposed framework is a first step in spotlighting significant steps needed for AVs to live up to the promise of improved mobility for older adults. Key areas for future work are listed below. Many of these steps are not developing organically within either the public or private sectors. Taking action requires a concerted effort from stakeholders specifically focused on older adult issues, as well as partners across the public and private sectors.

Defining Roles and Responsibilities – Both public and private sector actors are not adequately addressing many of the issues identified in the proposed framework. A key barrier is a lack of a shared understanding of who is primarily or even secondarily responsible for these issues. Stakeholders' understanding of their own or others' prospective roles and responsibilities differ. Defining these roles and responsibilities, with acceptance or consensus across stakeholders, is an essential step in shaping the new mobility and AV ecosystem.

Defining Policy Needs Around New Mobility, AVs and Equity – Policy will be critical to ensuring that the deployment of new mobility and AVs serve the needs of all older adults. While we have identified key topics around older adults' use and access to new mobility and AVs, this research has not specifically addressed potential regulatory options, which could be an important first step in creating a roadmap for government agencies and for older adult advocates. Regulatory and other policy options to explore range from safety regulation for AV technology to equity-promoting mechanisms. Such options include the use of fees, operational permits and limits, language requirements, training for drivers and other attendants, service area coverage and wait time minimums, and requiring low-income fares. Many state and local governments are currently grappling with new mobility and AV policy issues, making this a good time to explicitly include older adult concerns.

Promoting Universal Design for AVs and Other Forms of New Mobility – Principles of design that accommodate people across the spectrum of ability are well known. Incentives to promote these principles might need to be increased, along with incentives to provide human assistance required for older adults to access any new technologies.

Promoting Collective Action and Elevating Older Adult Issues Around New Mobility and AVs – Our project demonstrated the value of convening people from different sectors and expertise relating to transportation, new mobility, AVs, and older adults. Serving the needs of older adults as mobility options evolve calls for specific attention to those needs. While there are forums dedicated to emerging mobility generally, they seldom include aspects relating to older adults, and particularly those who are harder to serve. More cross-sector and multidisciplinary discussion, as in our roundtable, is an essential step to both capture the benefits of key, diverse stakeholder interaction as well as bring more attention to this topic.

Pursuing New Areas for Research - Progress in this arena would benefit from more research, including on such topics as:

- Engagement with older adults on how AVs and other forms of new mobility might address—or exacerbate—their unmet mobility needs and challenges. While a strong base of past research has defined unmet mobility needs,[30] the particular opportunities and potential pitfalls for older adults offered by AVs and new mobility remain largely uncharted territory.
- Understanding how various older adult subpopulations are currently served by existing transportation options and how they might be affected by the evolution of new mobility and AVs. Among the subpopulations of particular importance to understand are those older adults who have historically been hardest to serve because of physical or cognitive limitations or geography.
- Studying the impacts of multiple limitations (e.g., economic, geographic, and physical) concerning older adult use of new mobility and AVs.
- Best practices on demystifying new technology, such as AVs and the ridehailing and MaaS platforms through which vehicles will be summoned, and promoting technological fluency for older adults.
- Identifying service, system, and vehicle design modifications that enhance accessibility for a variety of user types. This could range from easy tweaks such as changes to the app and in-vehicle interface to increase visibility, to complicated and resource-intensive changes such as modifying the vehicle frame to allow wheelchair access. More broadly, this could include considerations of how supporting services such as the digital infrastructure can be optimized to support transportation for all older adults.
- Policy needs and options around new mobility, AVs, and older adults.

30 https://www.nadtc.org/wp-content/uploads/KRC-nadtc-Survey-Report-120718-FINAL_for-web508.pdf

CONCLUSION

The promise that AVs will radically improve mobility for older adults is not a given. As illustrated by the framework, a wide array of factors must be addressed to ensure older adults can access and benefit from these technologies, regardless of their income, abilities, or geography. Addressing these barriers requires coordination across sectors and various levels of government in a context where roles and responsibilities are currently unclear. Organizations with expertise and connection to older adult communities might need to take leadership roles to facilitate these conversations and elevate the needs of older adults. With the growth of disruptive transportation options offered by the private sector and a rethinking of public policies, it is critical that barriers to older adults (and others) are raised before AVs, new mobility, and MaaS are fully deployed and transportation inequities are exacerbated. Following the principles of Universal Design, advocacy for the design of AVs, vehicles, services, and infrastructure to benefit older adults will foster a more equitable new mobility and AV ecosystem for all.

APPENDIX 1: EXPERT CONTRIBUTORS CONSULTED

This project drew from prior research conducted by RAND and Urbanism Next,[31] supplemented by inputs from the AARP Public Policy Institute. We are grateful to the many subject matter experts who shared their ideas during the course of the project. Constituting a purposive sample, they were selected based on professional knowledge of the research team and suggestions from people consulted early in the project. Their affiliations include: AARP; Agile City Partners; City of Detroit, Office of Mobility Innovation; Contra Costa Transit Authority; Ford Mobility; Full Path; Insurance Institute for Highway Safety; Massachusetts Institute of Technology, AgeLab; Michigan Department of Transportation; MoGo; National Institute on Aging, Division of Behavioral and Social Research; San Francisco Municipal Transportation Agency; The Robotics Institute at Carnegie Mellon University; Toyota, Collaborative Safety Research Center; Uber; U.S. Department of Labor; U.S. Federal Transit Administration; University of Florida, Department of Occupational Therapy; University of Texas at Arlington, Department of Civil Engineering; Via; Voyage; and Waymo.

31 Ecola, Liisa, Steven W. Popper, Richard Silberglitt, Laura Fraade-Blanar. (2018). The Road to Zero: A Vision for Achieving Zero Roadway Deaths by 2050. RR2333. RAND Corporation.

Howell, A., Larco, N., et al. (2020). NSF Planning Grant Report: Multilevel Impacts of Emerging Technologies on City Form and Development. Urbanism Next Center. https://www.urbanismnext.org/resources/multilevel-impacts-of-emerging-technologies-on-city-form-and-development

Lewis, R., & Steckler, B. (2020). Emerging Technologies and Cities: Assessing the Impacts of New Mobility on Cities (NITC Final Report No. 1249). National Institute for Transportation and Communities (NITC). https://nitc.trec.pdx.edu/research/project/1249/Emerging_Technologies_and_Cities:_Assessing_the_Impacts_of_New_Mobility_on_Cities

Zmud, Johanna, Liisa Ecola, Peter Phelps, Irene Feige. (2018) The Future of Mobility: Scenarios for the United States in 2030. RR246. RAND Corporation.

Steckler, B., Larco, N., & Howell, A. (2019). Knight AV Initiative Preliminary Framework. Urbanism Next Center and CityFi.

APPENDIX 2: DESCRIPTION OF FRAMEWORK FACTORS

Individual Level: Factors relating to the self, including biology, personal history, physical and cognitive state, etc.[32]

- ***Demand-side factors:*** determine willingness and ability to access and use a transportation mode.
    - **Smartphone Access: Smartphone ownership cannot be assumed for older adults and presents a barrier downstream into new mobility access and usage.** Mobile internet access, commonly conducted using smartphone hardware, is the gateway to new mobility and AVs, particularly those using ridehail models. As just over half of older adults in the U.S. currently own a smartphone,[33] mobile internet access presents a sizable barrier to the use of these transportation technologies. In order to increase older adults' utilization of new mobility, efforts should first be made to increase access to the technologies connecting users to services – currently smartphones.
    - **Smartphone Use: Smartphones provide a capable and adaptable interface for human interaction with new mobility, but older adults' comfort, experience, and ability to navigate novel apps present a potential barrier for access.** The plasticity of smartphone applications allows for the interface to adapt to the user in some ways that will be beneficial for older adults (e.g., the ability to change to the size of buttons), but this plasticity is a double-edged sword. Frequent changes or updates to an application can be disruptive for older adults' use. This barrier can be partially circumvented by the addition of a telephone-accessible interface, a space that has already been entered by some private enterprises to mixed success.[34]
    - **Access to Online Payment: If new mobility is to be funded by the consumer (rather than, for example, being funded through government programs), the online nature of the platform implies online payment, which can be problematic for older adults.** Older adults are less likely to use mobile and online banking and are more likely to use cash and traditional card payments, be it due to habit, unfamiliarity with the technology, mistrust, or security concerns.[35] This issue can be partially addressed by offering the ability to pay by telephone with credit cards, or through a transportation credit account that can be filled via in-person, cash transactions.

32 https://www.cdc.gov/violenceprevention/publichealthissue/social-ecologicalmodel.html

33 Anderson, M. (June, 2019). Mobile technology and home broadband, 2019. Pew Research Center, Washington, D.C. https://www.pewresearch.org/Internet/2019/06/13/mobile-technology-and-home-broadband-2019/

34 Emerson, S. (April, 2017). "GoGoGrandparent" is overcharging seniors for Uber rides, and drivers are pissed. Vice. https://www.vice.com/en_us/article/bmexq3/gogograndparent-startup-seniorolder adults-uber-drivers-

35 The Pew Charitable Trusts. (October, 2019). Are Americans embracing mobile payments? https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2019/10/are-americans-embracing-mobile-payments#:~:text=Although%2088%20percent%20of%20Americans,linked%20to%20a%20mobile%20

The implementation of a uniform payment method across platforms or within a single platform that covers all transportation options (MaaS) can also help simplify and streamline payment. Doing so would need to factor in subsidies for transportation on which some older adults depend.

- **Affordability of Services: Older adults generally travel less than younger adults, increasing the relative cost per mile traveled when using personally owned vehicles. Due to fixed costs of car ownership (e.g., insurance) and age-related reductions in travel,** the relatively higher cost per mile of vehicle ownership could make shared alternatives more affordable and appealing for older adults.[36] In regard to the cost of shared transportation options, the final cost and affordability will ultimately be set through a collaboration between providers and government. Subsidizing the cost of transportation (for everyone or for particular populations, such as older adults) can increase access for older adults by making it more affordable. Such programs exist for conventional transportation, and programs for new mobility options are being investigated by both public and private sectors.

- **Language Barriers: One of the benefits of a smart interface is language translation capability, but older riders may require interaction with other humans and encounter language barriers.** This issue may be compounded in areas with large populations of older adults that have a primary language other than English. In-app translation features, like those offered by Uber,[37] are beneficial but use by older adults might require additional training or experience.[38]

- **Barriers of Trust, Emotions, and Attitudes towards Technology: Older adults report lower levels of comfort and perceived self-efficacy for the use of technology, but this trend is alleviated with increased experience, education, and being in a more recent birth cohort.**[39] Older adults' trust and attitudes towards new mobility technologies have the potential to act as significant barriers to their use. Experience with technology, including automated vehicles, is directly linked to comfort, trust, attitudes, and the willingness to use the technology. Providing older adults with hands-on experience using new mobility technologies can be an important method of overcoming these barriers.[40] As these technologies are introduced to new markets, companies and advocacy groups should consider public demonstrations that offer hands-on experience (e.g., SAE Demo Days) in an effort to increase acceptance and foster positive attitudes.

36 Subject matter expert interview

37 Akil, A., & Vanieva, O. (February, 2020). Your ride, redesigned: Introducing new features that help make pickups more seamless. Uber. https://www.uber.com/newsroom/seamless-pickups/

38 In principle, technology could be more helpful than human drivers, whose language skills will vary quite broadly.

39 Lee, C. C., Czaja, S. J., Moxley, J. H., Sharit, J., Boot, W. R., Charness, N., & Rogers, W. A. (2019). Attitudes toward computers across adulthood from 1994 to 2013. The Gerontologist, 59(1), 22-33.

40 Liu, P., Xu, Z., & Zhao, X. (2019). Road tests of self-driving vehicles: Affective and cognitive pathways in acceptance formation. Transportation Research Part A, 124, 354-369; Subject matter expert interviews

- **Physical and cognitive barriers: Barriers to summoning, getting to, entering and exiting the transportation vehicle, as well as challenges during transit.** Physical and cognitive abilities exist along a spectrum. Broadly, these abilities can be grouped into four service categories:[41]
    - Hand-to-hand assistance (H2H): individuals requiring assistance and/or oversight for all segments of the trip, and who are unable to complete any trip portion independently. These individuals may face the greatest barriers to new mobility and AV use due to challenges summoning the vehicle, identifying the vehicle, getting to the vehicle, understanding route progression, etc. It is possible having an aid chaperoning the individual may reduce or eliminate these barriers. Bringing services to the individual may reduce trip needs.
    - Door-to-door service (D2D): individuals who are able to move and navigate with some degree of independence, but who require at least some assistance getting to and into the vehicle. Services to minimize barriers include options such as requesting a minimal walk time when summoning the vehicles, in-ride audio support, and requesting the vehicle honk to aid identification. Depending on the individual's understanding of the environment surrounding him or her, more intensive vehicle modification (e.g. making the vehicle wheelchair accessible) may be required.
    - Curb-to-curb service (C2C): Individuals able to travel to the curb but may require some assistance entering or exiting the vehicles. Modifications to the vehicle (e.g. large doors, kneeling vehicles, grab bars, etc.) may assist individuals who need C2C services, as would some of the services for D2D.
    - Area-to-area service (A2A): Highly ambulatory individuals (e.g. able to walk to and navigate to an autonomous bus stop a quarter mile away) who can use A2A services are unlikely to face physical or cognitive barriers to AV access and use.

- ***Safety factors:***[42] determine if the mode is safe for the older adult from the individual level
    - **Non-crash-related health factors: The ride should not create or exacerbate health problems.** Injuries can occur when interacting with the vehicle. Vehicle design should minimize the possibility of, for example, tripping and falling when entering or exiting the vehicle (concerns that high-riding sport-utility vehicles demonstrate are not universally addressed).[43] In addition, vehicle acceleration and deceleration must be sufficiently smooth so as not to induce motion sickness or whiplash, from which older adults may have more difficulty recovering.[44] Where there are human drivers or attendants, special training to support accessibility might be appropriate.

41 Fraade-Blanar, L and Whaley, C. Non-Emergency Medical Transportation and Rideshare. In Review. RAND 2020.

42 Safety factors straddle individual and organizational levels, with two specific factors (non-crash-related health factors and personal security concerns) are individual factors, and two specific factors (crash prevention and vehicle occupant or pedestrian safety) as organizational factors.

43 Subject matter expert interviews

44 Sanjay Yadla,corresponding author John K. Ratliff, and James S. Harrop. Whiplash: diagnosis, treatment, and associated injuries. Curr Rev Musculoskelet Med. 2008 Mar; 1(1): 65–68.

- **Personal security concerns: Older adults should feel secure during the ride.** Problems, potential or realized, with other vehicle occupants may exist when sharing a transportation environment with drivers or with other passengers. (e.g., concerns over aggression, needing assistance). When using public transit, older adults may feel more comfortable when traveling with companions—friends, family, other older adults, etc.[45] There may also be concerns about cybersecurity and privacy and that the AV owner or operator may leak or abuse personal information about the older adult.[46] This may be particularly salient for older adults who request certain types of rides in relation to their medical needs (e.g., daily rides to a dialysis center or drug treatment facility). Privacy is illustrative of a broader set of issues relating to trust in new technology more generally. Such issues, roundtable participants discussed, can present emotional barriers to using AVs or other new mobility technologies.

Organizational Level: Factors describing the institutional and/or commercial influences

- ***Safety factors:*** determine if the mode is safe for the older adult from the organizational level.
  - **Crash prevention** and **Vehicle occupant or pedestrian safety: Risk of crash, and in the event of crash, risk of injury must be minimized. Automated driving systems, vehicle design, and active vehicle safety systems** such as airbags, must protect potentially fragile older adults.[47] Design, development, and testing of these safety features should include older adults during all steps of the process.
- ***Supply-side factors:*** determine availability and fit to user need for a transportation mode.
  - **Accommodation of goods or aids: To be effective for older adults, transportation services must accommodate needed paraphernalia, including goods, groceries, suitcases, walkers, or wheelchairs for the mobility-impaired.** Older adult trips often involve transporting not only an individual, but also a range of goods and/or aids for movement. Approximately a quarter of all older adults use mobility aids[48] and require them for travel at their destinations and to and from vehicles. To meet older adults' needs, new mobility and AV trips need to accommodate the easy storage of these devices or other goods in ways that do not hinder riders' entrance or exit from vehicles.

45 Subject matter expert interviews

46 For an example with ridehail: Binette, Joanne and Kerri Vasold. 2018 Home and Community Preferences: A National Survey of Adults Age 18-Plus. Washington, DC: AARP Research, August 2018. https://doi.org/10.26419/res.00231.001

47 Federal Motor Vehicle Safety Standards provide a first line of protection for occupant protection and vehicle crashworthiness. They presume a capable human driver, however, which will not be the case with AVs.

48 Gell, N. M., Wallace, R. B., LaCroix, A. Z., Mroz, T. M., & Patel, K. V. (2015). Mobility Device Use in Older Adults and Incidence of Falls and Worry About Falling: Findings from the 2011–2012 National Health and Aging Trends Study. Journal of the American Geriatrics Society, 63(5), 853–859. https://doi.org/10.1111/jgs.13393

- **Travel options fit with user needs: Service providers need to offer travel options, origins and destinations that fulfill older adult needs.** Older adult trip destinations, lengths, and purpose are often different than those of the general population.[49] Not all trips are appropriate for AV use. If there is not a good fit between offerings and older adult needs, there will be minimal use of services. One large barrier to fulfilling this fit is a lack of understanding about currently unmet travel needs of older adults.

- **Travel options fit with environmental conditions: Services need to work in challenging environmental situations.** If older adults are to rely on new mobility and AVs for their transportation needs, these services will need to not only work for typical trips, but also trips in difficult weather, extreme traffic and during natural disasters. COVID-19 has also demonstrated new appreciation for sanitation or hygiene in vehicles with frequent change among riders.

- **Availability of transportation services in your area: Older adults need mobility solutions that serve their neighborhoods and can take them everywhere they need to go.** Not all areas are equally easy to service and there is a tendency for transportation companies to focus on dense, higher income, and centrally located neighborhoods that offer more opportunities for profit.[50] For proposed mobility solutions to serve the broad needs of older adults, all origins and destinations, including those in exurban and rural areas, need to be covered.

- **Consistent transportation service availability: Older adults need mobility solutions they can rely on into the future.** Recent history has shown that new mobility companies enter and exit markets based on profitability and can shift offerings with little warning.[51] Older adults need consistency and reliability of services and to know that the lifestyle and housing choices they make will continue to have viable mobility options into the future.

- **Bias in availability: Everyone needs to have equal access to rides, regardless of age, race, ethnicity, ability, or income levels.** Discrimination can limit mobility options and severely impact older adults' quality of life. Programs that eliminate explicit and implicit bias in transportation services are key ways to help guarantee equal access.

49 Rohr, C., Whittaker, B., Fox, J., Glenesk, J., & Collins, J. J. (2018). Latest evidence on factors impacting road traffic growth: An evidence review. EP-67750. RAND Corporation.

Zmud, J., Green, L., Kuhnimhof, T., Le Vine, S., Polak, J., & Phelps, P. (2017). Still going… and going: The emerging travel patterns of older adults. Retrieved from https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/company/downloads/en/2017/2017-BMW-Group-IFMO-Publication.September.pdf

50 Wang, M., & Mu, Lan. (2018). Spatial Disparities of Uber Accessibility: An Exploratory Analysis in Atlanta, USA. Computers, Environment and Urban Systems 67 (January): 169–75. https://doi.org/10.1016/j.compenvurbsys.2017.09.003

Ghili, S. & Kumar, V. (2020). Spatial Distribution of Supply and the Role of Market Thickness: Theory and Evidence from Ride Sharing. SSRN Scholarly Paper ID 3520187. Rochester, NY: Social Science Research Network. https://papers.ssrn.com/abstract=3520187.

51 As recently seen with electric scooter-rentals: Herrera, S. (2020). Scooter startup Lime exits a dozen markets, cuts jobs. The Wall Street Journal, https://www.wsj.com/articles/scooter-startup-lime-exits-a-dozen-markets-cuts-jobs-11578619517

Physical Environment Level: Factors related to the physical infrastructure

- ***Land use and transportation policy factors:*** relate to how the roadways, public transportation, and adjacent physical environments are engineered and regulated to optimize older adult mobility.
    - **Curb and Sidewalk Management: Older Adults may have mobility limitations that are exacerbated by inadequate design, maintenance and management of curbs and sidewalks that make it difficult to benefit from new mobility/AV services.** A sidewalk may be inaccessible in a wheelchair due to tree roots, dockless e-scooters blocking the path, or lack of curb cuts at the intersection. The adjacent curb zone may be devoted to private car parking and create an unsafe or too distant pick up and drop off zone for older adults to reliably use ridehailing services. Models to quantify curb use and allocate curb space may need adjustments to equitably value the different use patterns of curbs that serve as pickup and drop off points for older adults.[52]
    - **Street cross-section design: Right-of-way allocation currently favors the private vehicle and, as older adults shift away from driving themselves, the design of streets may inhibit their adoption of alternative means of transportation.** In order to fully adopt shared new mobility and AV services, older adults will require accessible sidewalks, safe pedestrian crossings and comfortable, dedicated pick up and drop off zones near their points of origin and destination. Within the roadway, how the space is used (street cross-section design) can increase the safety of older adults as potential AV passengers and pedestrians (e.g., by narrowing lanes and encouraging lower speeds). It is also possible to improve the reliability and efficiency of shared services by allocating lanes for shared new mobility and AV services and public transit.[53]

52 McAdam, T., Martin, P., Medeiros, J., Nabors, D. et al. Curbside Management Practitioners Guide. n.d., 50.

53 Schlossberg, M., Riggs, W., Millard-Ball, A., & Shay, E. (2018, January). Rethinking the Street in an Era of Driverless Cars. University of Oregon. https://cpb-us-e1.wpmucdn.com/blogs.uoregon.edu/dist/f/13615/files/2020/01/RethinkingtheStreet.pdf

Social Environment Level: Factors related to societal mores, political initiatives, and cultural norms[54]

- ***Transportation systems factors:*** relate to the broader transportation ecosystem, as well as considering spillover or secondary effects of other changes which may affect mobility.
    - **Availability of public transportation options: New mobility and AV options that lead to reduced public transport offerings could reduce the overall mobility of older adults.** Ridehailing often competes with and pulls riders away from public transit,[55] and there is a concern that AVs will simply accelerate that trend. Reduced transit offerings and limited frequency of service could indirectly reduce mobility options for older adults.
    - **Availability of last-mile options: Older adults need mobility solutions that can complement and facilitate transit trips.** New mobility and AVs could provide mobility solutions for safely and conveniently getting older adults to and from transit. These so-called first- and last-mile segments of door-to-door trips often lack solutions that accommodate the needs and safety concerns of older adults (other than some of those involving human drivers).
- ***Secondary response factors:*** relate to side-effects or byproducts of changes to the transportation ecosystem.
    - **Other impacts of new mobility/AVs on transportation systems: Ensuring net positive outcomes.** New mobility and AVs should be deployed in ways that do not increase congestion and emissions or reduce safety for pedestrians or general health.

54 https://www.cdc.gov/violenceprevention/publichealthissue/social-ecologicalmodel.html

55 Graehler Jr., M., Mucci, R. A., & Erhardt, G. D. (2019, January 13). Understanding the Recent Transit Ridership Decline in Major U.S. Cities: Service Cuts or Emerging Modes? 98th Annual Meeting of the Transportation Research Board, Washington, DC. https://uknow.uky.edu/research/understanding-traffic-impacts-uber-lyft-greg-erhardt

Schaller, B. (2018). The New Automobility: Lyft, Uber, and the Future of American Cities. Schaller Consulting. http://www.schallerconsult.com/rideservices/automobility.htm

APPENDIX 3: PRELIMINARY LITERATURE REVIEW LEADING TO FRAMEWORK DEVELOPMENT

We conducted a non-systematic landscape scan at the outset of our work, consulting published material and identifying projects engaging older adults with new mobility and/or AVs. This outline describes the current state of knowledge relating to older adult benefits/harms due to new mobility and AVs and the challenges of access to these services. References cited are presented at the end, and several are included in footnotes to the main text.

POTENTIAL FACTORS

Use Cases: How do Older adults get around currently? What are current patterns?

01. Mobility/Daily Trips/Errands

- **According to the National Household Travel Survey (2017), 82.4 percent of adults age 65+ report themselves to be drivers.** 53.4 percent of older adults reported taking three or more trips on a random day.
- **There is likely pent up transportation need.** The majority of older adults with transportation limitations who participated in an unlimited ride-share program reported an improvement in quality of life (90 percent), greater ease in medical visits (68 percent), and increased social interactions (74 percent). Thirty-five percent increased their physical activity (Raphael, 2019).

02. Non-Emergency Medical Trips

- **For those who can use curb-to-curb transport, ridehailing provides an excellent if currently not-widely-used option.** Transportation problems are often cited as a barrier to receiving care and medical compliance (Edrington S, Cherrington L, Burkhardt J, et al 2018). Non-emergency Medical Transportation (NEMT) may be paid for by Medicare Advantage, for those who have this coverage. A pilot study showed Medicare Advantage customers using ridehail-based NEMT had a lower average wait time (particularly on return trips) and a higher rate of on-time pick-up compared to those using other types of NEMT. Rides cost on average 39 percent less than the alternative NEMT (Powers et al. 2018). One study found a significantly lower rate of missed primary care appointments among those traveling with ridehail-based NEMT compared to all other modes (Kim, et al. 2009).

03. Public Transportation

- **Older adults prefer to use privately owned vehicles to meet their transportation needs, but express willingness to use public transportation.** In a mixed-methods study comprised to focus groups and a survey (Peck, 2010), older adults' primary concerns with public transportation were listed as the lack of access to service (e.g., lack of nearby bus stops) and having to wait for transportation in inclement weather; issues that are not present for the personal automobile. Negative perceptions of public transit (e.g., fear of safety relative to inconsiderate passengers, discourteous and unhelpful operators, being able to find a seat before movement of the vehicle) were also cited as barriers, particularly among older adults that have not traveled using public transit. Additionally, in a 2017 survey of U.S. adults with disabilities, 47.9 percent of respondents indicated that the public transportation system was inadequate, in that "it did not get them where they needed to go, when they needed to get there, and in a reasonable amount of time" (Bezyak, Sabella, & Robert, 2017, p. 56).

04. Shared-Use Mobility

- **Shared mobility (especially carshare, ridehail/volunteer-provided transportation service, and bikeshare), currently faces an access equity problem for older adults and people with disabilities.** The design and policy that defines shared systems is simply not inclusive enough at the present stage of development. This stems from a variety of barriers including physical, geographic, economic, and technical. (LaRosa, NATDC, March, 2020). Universal mobility as a service is a concept to address these barriers that currently foster an inequitable transportation system. Mobility as a Service (MaaS) is a shift from privately owned transportation to mobility solutions consumed as a service, often understood as an app/website to plan and purchase transportation services. Universal MaaS expands on the concept to ensure all users' needs are met regardless of age, disability, income, or geography, for example scheduling and paying for a demand responsive bus with wheelchair accessibility (Lynott, 2018).

05. Emergency Travel (e.g., travel to hospital during acute medical event)

- **No material available but there are likely to be challenges here.** Currently ridehail drivers do not assist passengers officially (although some do unofficially, and some TNC pilot programs are exploring this further).

06. Travel with Packages

- **No material available but there are likely to be challenges here.** Currently ridehail drivers do not assist passengers officially (although some do unofficially, and some TNC pilot programs are exploring this further). Also, for the mobility-impaired, packages could include walkers or wheelchairs.

Service Access Factors: What determines if an older adult could feasibly use the service?

01. Smartphone Access

- **More older adults own smartphones than ever before, but they still lag behind younger age groups.** As of 2019, over half (53 percent) of older adults now own smartphones, an increase from only 30 percent in 2015. While that is a dramatic increase, that still leaves a sizable portion of older adults without access to transportation options that require smartphone access, such as ridehail (Anderson, 2019).

02. Smartphone/App Use and Familiarity

- **Ridehail use is growing among older adults faster than other age groups, but still lags behind younger age groups in terms of total use.** Only a quarter of U.S. adults aged 50+ had used smartphone app-based ridehail transportation (Jiang, 2019). There are anecdotal reports that a distrust of the monetary transaction component of the apps dissuades some older adults from using them (Span, 2019, Tooley, 2019). Lack of knowledge on multiple aspects of ridehail operations, such as payment and how to book rides, is also a barrier for older adults to use ridehailing services (Tooley, 2019). Some companies have been created to bridge the gap between non-smartphone using older adults and ridehail companies by allowing individuals to use Lyft and Uber with only telephone access (e.g., "GoGoGrandparent"). While improving access, these services operate by adding a surcharge to the normal price of ridehail usage and may not be a suitable solution for older adults that cite cost as a main deterrent of ridehail use. It is important to note, this third-party intermediary system is imperfect and there have been complaints both on behalf of the older adult consumers (e.g., prices) and the ridehail drivers (e.g., liability issues, that they are being asked to provide additional service without additional training or payment; Emerson, 2017).

03. Methods of Payment (Banked/Unbanked)

- **Nearly all older adults have checking accounts, but many fewer bank online and an even smaller percentage conduct mobile banking transactions.** 96 percent of adults age 65 and older have bank accounts, and 98 percent of older adults with bank accounts have a checking account (FDIC, 2017). In terms of digital banking, older adults are more likely to use traditional payment methods compared to mobile payments. A 2013 study found that older adult internet users were less likely to bank online (47 percent; Fox, 2013) and far less likely to conduct mobile banking (14 percent; The Pew Charitable Trusts, 2019) compared to younger age groups.

- **Integrated payment systems at the regional, state, or national level could tackle payment barriers that prevent some users from having access to new mobility options.** Three key components of ensuring greater transportation equity are fare capping for public transportation, mobility bundles (in the future), and increasing the number of services that can be purchased through public transportation fare systems or a regional/statewide/nationwide integrated payment system.

This type of mobility marketplace is enabled by the data standardization of trip elements, such as the Transactional Data Specification (TCRP Report 210, 2019), OpenTripPlanner, and GTFS. An OpenTripPlanner extension can show real-time transit and other shared mobility information and route walking paths based on information in Open Street Map. If enacted as part of an overall marketplace MaaS with an IPS, many users who do not have access to ride sourcing services today because they are unbanked, underbanked, or lack smartphones or data plans would gain access to a broad spectrum of mobility options. A government entity managing the business rules of the mobility marketplace can ensure equitable service for lower income and minority areas and for people with disabilities. Developing a transportation network that allows equal access to all travelers will require more coordination between institutional partners, oversight of private mobility services, and political will to change the status quo. (O'Hara, 2020).

04. Language

- **Language barriers most often arise with special requests or other communication with drivers/companies, and some companies are introducing translation features to address this issue.** Normal interaction with trip planning apps likely occurs in the user's chosen language. But, in ridehail situations, the driver and passenger may not share a common language. Uber has introduced an in-app translation feature across 100+ languages to help facilitate communication (Akil & Vanieva, 2020). This may prove to be a particular benefit for older adults who have special requests for directions (e.g., stop as close to the front door as possible) or assistance (e.g., help with storage of a mobility aide).

05. Affordability/Costs of Services

- **Early indications are that cost is a major barrier for ridehail use among certain older adult demographics.** After gaining experience using temporarily free ridehail services, 80 percent of older adults indicated that they would likely continue to use the service. For the remaining 20 percent, cost was listed as a main deterrent (Saxon, Ebert, & Sobhani, 2019).

06. Geographic Location: Urban/Rural Divide

- **Geography presents a major barrier to the use of new mobility in rural areas (e.g., economic viability relating to population density and geographic limitations, mobile data speed and availability). Adults living in rural areas also have comparatively more negative perceptions of AVs compared to those who live in urban areas.** Lack of transportation access is a common issue for rural adults, but business issues (i.e., low profit margins) have proven to be a substantial barrier for the implementation of new mobility options in these communities. Possibly in response to this lack of access and resulting experience, perceptions of new mobility options like AVs among rural residents are more negative when compared to urban dwellers (König & Neumayr, 2016).

Vehicle Availability Factors: Are vehicles available when and where they are needed?

01. Deployment Locations

- **New mobility options have tended to be deployed in denser areas, pointing towards similar potential deployment for AVs.** Shared transportation modes are often more profitable in dense areas where there is a higher concentration of potential riders and potential origins and destinations. This has led to increased deployment in these areas (Wang and Mu, 2018; Ghili et al., 2020), but has the side effect of underserving individuals less likely to live in these communities (e.g., older adults, people of color; Secter & Bordens, 2013). Cities, however, have created regulations that incentivize new mobility companies to expand beyond these most lucrative areas to provide broader geographic coverage.

- **Rural areas are underserved by new mobility compared to urban and suburban areas.** New mobility options have expanded to various metro areas around the country and are often available both in central cities and in the surrounding suburbs (Uber, 2020). While Uber and Lyft claim to have statewide service in some states, studies have shown that actual availability of vehicles is either non-existent or minimal to a point of being unusable (Joseph, 2018, Pierson, 2017). Rural areas, because of lower population density and the difficulty this raises for service, have been slower to embrace the new mobility paradigm. For instance, only 19 percent of rural residents used ridehail in 2018 compared to 45 percent in urban and 40 percent in suburban areas (Jiang, 2019).

02. Consistency of Availability

- **Long-term reliability of service is a challenge for shared mobility.** New mobility business models are in their infancy and transportation has historically been a low-margin industry, making profits difficult. This has led to large shifts in new mobility offerings as business strategies change and some transportation providers limit or terminate service in certain markets (Short, 2019; Gilmer, 2020). This creates long-term challenges for users who have come to rely on services and make decisions about where they live or whether to buy a car based on new mobility service availability. Shared or fleet AV companies could face similar business and profitability challenges that would have strong repercussions for those who rely on service for essential needs.

03. Bias from Drivers/Customers

- **New mobility options have a mixed record in terms of racial justice issues.** On the one hand, ridehailing has been shown to improve, but not eliminate (see Mejia & Parker, 2020) racial and ethnic discrimination in terms of trip cancellation or wait times - a large improvement to taxi services, which have a strong documented bias against black riders (Brown, 2018). Conversely, new mobility has seen much more use in wealthier areas (Jin et. al., 2019), leaving lower income and predominantly minority neighborhoods underserved and without as many feasible mobility options. Some studies have, however, not seen this spatial bias of ridehail availability in terms of race and income (Wang and Mu, 2018).

- **New mobility options have a mixed record in terms of age-bias.** Drivers (of ridehail and public transportation vehicles) are not always attuned to the needs of their passengers. Lack of familiarity with drivers, uncomfortable interactions, and lack of tolerance regarding disabilities or service animals were circumstances brought up repeatedly during outreach activities. Transportation Network Companies (TNCs) should seek to follow the same disability sensitivity and passenger assistance training protocols and procedures that paratransit services have enacted for their drivers, using ADA guidance as a start.

04. Privately Owned AVs Versus Shared Fleets

- **While the future is uncertain, many within the industry believe the AV future will primarily consist of fleets.** AV deployment as fleets or individually owned vehicles is largely debated (Motavalli, 2020). Most AV companies are pursuing fleet models, but a few companies seeking to transition from lower to higher levels of automation - most notably Tesla - are focused on individual ownership. Business models for fleets include ownership by third party companies, employers, or public agencies (Stocker and Shaheen, 2017). The arguments against private ownership revolve mostly around issues of maintenance and cost (S. 2018; Gindrat, 2020). AVs involve highly technical systems that are safety-critical and need constant maintenance. Keeping systems updated and functional is more feasible in a fleet scenario where continuous professional service and updating is possible. In terms of cost, many project the cost of AVs being significantly higher than that of a conventional car for the foreseeable future. This would make individual ownership only possible for a small slice of the population, while fleet usage increases the amount each vehicle is used per day and can spread the cost over a larger population, bringing the cost per mile driven substantially down.

Vehicle Factors: What determines if an older adult can cognitively and physically access the transportation option?

01. Ability to Enter/Exit Vehicle (Vehicle Design)

- **Much of the current research and dialogue surrounding AVs pertains to how they are operated and not to other design characteristics.** Simply adding automation to existing vehicle designs misses the opportunity for vehicle redesign with an eye towards increased accessibility for people with disabilities and older adults (NCMM, 2018). Some companies (e.g., Zoox) are currently designing AVs from the ground up with new interior designs, but it remains to be seen if these designs will improve accessibility – particularly for entering and exiting the vehicle (e.g., Crizzle, Vrkljan, Kajaks, Gish, & Fleisig, 2014; Herriotts, 2015; Kajaks, Crizzle, Gish, Fleisig, & Vrkljan, 2015) – alongside safety and aesthetics. In focus groups, Older Adults have expressed the most interest in AVs with spacious, low-floor and accessible vehicles to enable traveling with friends with a variety of mobility devices (Faber, 2020).

02. Psychological/Cognitive Barriers to Use of Service

- **Current surveys show that older adults have greater concern about AV safety, lower perceptions of safety, and are less aware of AVs compared to younger adults, but these metrics will likely improve with experience.** Trust and comfort are important factors for the acceptance of automated technologies, but these factors are often a product of experience. For example, trust and perceived safety increased among older adults after exposure to an AV simulator or a ride in an AV shuttle (Classen, 2020) and after focus group discussion where a small number of pro-AV participants alleviated safety concerns of other participants (Frison, Aigner, Wintersberger, and Riener, 2018, Faber, 2020). Though AVs are a new technology where few individuals have hands-on experience, there is some evidence that, relative to younger adults, older adults' less positive attitudes towards technology in general (e.g., Czaja, Boot, Charness, & Rogers, 2019) extend to automated vehicles as well (Abraham et al., 2017; Eby, Molnar, & Stanciu, 2018; Souders & Charness, 2016; Ward, Raue, Lee, D'Ambrosio, & Coughlin, 2017).

03. Special Needs

- **Assistance with moving between the home, vehicle, and destination can be a barrier to many frail older adults and will likely require human assistance given the current state of technology.** Remaining to be solved is the "first/last 10-meter issue" or the "first/last-50-feet-problem." How will individuals move from their travel origin to the vehicle or from the vehicle to the destination (Coughlin, 2017; Czaja et al., 2019)? When the passenger is someone with limited mobility, at the current state of technology, this issue will still likely be addressed with another human present to assist the rider.

- **TNCs have partnered with third party wheelchair-accessible vehicle (WAV) providers to pilot programs in select markets (large cities), but access is still inadequate in most of the country.** For example, Lyft's Access mode outlines three tiers of accessibility: markets with vehicles that accommodate a full-sized, non-foldable wheelchair, vehicles that accommodate foldable mobility devices, and those with no access where the app will direct users to local accessible vehicle dispatch services (Lekach, 2019, Lyft Accessible Vehicle Dispatch). Additionally, Uber's WAV program offers rides in vehicles that can accommodate motorized or non-folding wheelchairs for a small additional fee, but access is limited to select urban markets.

Safety Concerns: What are the broad safety concerns and the safety concerns specific to older adults?

01. Vehicle Safety (Driving/Travel)

- **Specific to AVs, much of the safety concern for older adults is unlikely to differ from that of middle-aged and young adults and children, But, if the crash type and severity profile of AVs were to differ from that of conventional vehicles, older adults may not benefit as other age groups would.** Although contentious due to differential exposure, older adult driver crash risk per vehicle miles traveled (VMT) increases at around age 65. Their ability to safely operate a vehicle may be diminished due to polymorbidity, impaired physical movement, or polypharmacy (Clinician's Guide to Assessing and Counseling Older Drivers, 2016). Additionally, frailty is a concern for many older adults, passengers and drivers alike. Age brings increasing susceptibility to adverse health outcomes following a stressor event. A motor vehicle crash is more likely to result in hospitalization, disability, and even death. (Cox, 2020, Cicchino, 2015). Consequently, if AV-involved crashes were of higher force but less frequency, older adults may bear a disproportionate burden of the new crash profile.

- **Due to diminished driving abilities among some older adults, ADAS technologies provide a unique potential to correct for declines in particular driving tasks.** Older adults benefit from ADAS technology, including crash mitigation technology. In terms of crash prevention technology, a survey of experts found that the top technologies likely to help older drivers including smart headlights, automatic crash notification, and reverse monitoring systems/backup cameras (automation was not included in the study; The Hartford, 2015). Older adults have concerns about the safety of AVs (Faber & van Lierop, 2020).

02. Emergency Situations (external or of the passenger)

- **There is limited information known here.** Theoretically, new mobility options could alert EMS of a crash (although such systems are already in place, e.g. OnStar). In an older adults focus group study, participants stated that telematics systems would be important to include in AVs (Huff, DellaMaria, Posadas, Brinkley, 2019).[56]

03. Aggression/Assistance Concerns (of drivers and from other passengers in shared ride)

- **Because there are no drivers for AVs, this may be less germane.** But for new mobility options that include rideshare and a human driver, it initially seems likely that the barriers to rideshare do not focus on the human driver aspect (and therefore would not be solved by removing the human driver) (Payyanadan & Lee, 2018).

56 Telematics systems track real-time information about the performance of a vehicle and electronically submit that information to a third party. Data may include location, speed, idling time, harsh acceleration or braking, fuel consumption, vehicle maintenance issues, weather, and road conditions. The system can also send distress signals to emergency response teams. Telematics systems are in use today to transmit information from a vehicle to an insurance company or auto repair shop, but will likely take on increased importance with AV deployment.

- **There is little information on older adult willingness to engage in a shared ride.** Anecdotal evidence suggests it may be less palatable, possibly because of privacy or security concerns.

04. Safety Concerns due to Cognitive or Physical Abilities

- **Depending on the service model, older adults with cognitive or physical impairments may not be able to use new mobility options without modifications to the vehicle and/or the service model.** Although driving skills, like walking, are a highly automated ability that does not require effortful cognitive engagement (Snellgrove, 2005), monitoring ride progression represents a new and challenging skill. Older adults may need route progression updates, and, among those with impairments, a companion. This may be especially true for older adults with any sort of disability, who already have difficulty using traditional ridehail-based passenger vehicles (NADTC 2017, SMFTA 2019). Modifications to the vehicle and service are needed throughout the pre-ride, ride, and post-ride process: to safely secure mobility devices and signal to the AV that the passenger is ready to move, to communicate with the service provider in an emergency, to provide users with guidance on safely exiting the vehicle to avoid potential hazards (AVs & Increased Accessibility, 2019).

Mobility/Accessibility Benefits or Harms: On a societal level, what are the mobility/accessibility benefits or harms to broad transportation systems?

01. Increase/Decrease of Mobility Options, Impacts on Transit Use, First/Last Mile Solutions

- **Ridehailing (and eventually AVs) could be drawing riders from transit, potentially limiting transit options for all.** (Ridehail as proxy for AV future). Most studies investigating this topic report that ridehail trips are replacing transit trips. One study of various metro areas in the U.S. found that the introduction of TNCs into a market led to an average 1.3 percent drop in heavy rail ridership and a 1.7 percent drop in bus ridership per year for each year after ridehail service launched (Graehler, Mucci and Erhardt, 2019). Another report found that 60 percent of ridehail trips would have been done on transit, walking or biking (Schaller, 2018). These trends point to a potential overall substitution of ridehail, and eventually AV, trips for transit trips. 33 percent of riders in the San Francisco area specifically replaced transit trips with ridehail trips (Shaheen and Chan, 2016). This could lead to reduced transit service (in terms of coverage and frequency), severely impacting those older adults who rely on transit for their transportation.

- **Ridehailing (and eventually AVs) could be a complement to transit and help with first/last mile access.** Some have found that ridehailing actually complements transit service (Boisjoly et. al., 2018), potentially serving as a first/last mile solution, and increase ridership by 5 percent over two years (Hall, Palsson and Price, 2018). This complementing of transit may be differentiated by the urban environment and the type of transit (commuter vs local service) with commuter transportation possibly seeing more complementing than competition (Graehler, Mucci and Erhardt, 2019).

Land Use and Transportation Policy: How does current policy influence older adult mobility, and how will/could this change?

01. Curb and Sidewalk Management Policy

- **The rise of new mobility and e-commerce has created new demands for the curb and spurred discussion of efficient and equitable management of the curb.** Curbside management organizes the curb to prioritize mobility and safety for all and requires an inventory of existing curb usage and policies. Cities are exploring the deployment of flex zones along the curb to allow for passenger and commercial loading and new mobility services along a corridor at different locations or times of day (McAdam, n.d.). Models to quantify curb use (such as the Curb Productivity Index, which measures passengers served per hour per 20 ft. of curb) may need adjustments to equitably value the different use patterns of curbs that serve as pickup and drop off points for older adults. Managing curbsides at a neighborhood scale makes it possible to assign curbside uses that don't need to be directly in front of a destination. In other words, reassigning multi-hour parking to sidestreets frees up curb space directly in front of main building entrances for accessible pick-up/drop off that must be close to the intended destination (NACTO). New mobility technologies on the sidewalk, such as today's inconsistent parking of dockless e-scooters and future AV drone delivery vehicles, can also pose problems for older adults' access to pick up / drop off points, and should be channelled to appropriate locations.

02. Street Cross-Section Design

- **The widespread adoption of Level 4+ AVs has the potential to free up right-of-way (ROW) space through the narrowing of lanes, eliminating on-street parking, and reducing the number of lanes due to increased throughput.** Rather than the current street prioritization of private vehicles that does not always serve the mobility needs of older adults, future streets could devote more space to fleets of shared AVs (operating similar to current microtransit or ridehail models) that increase older adult mobility. However, this unlocking of street space is highly dependent on policies to encourage shared autonomous vehicle fleets and mitigate anticipated increased congestion, which has been documented as a result of ridehailing (Schlossberg et al, 2018,). The narrowing of lanes and potentially lower speeds for AVs could also improve older adults' safety as pedestrians.

ADDITIONAL TOPICS

01. Knowledge and Use of Ridehailing by Older Adults

- **When older adults are educated and supported in the use of ridehailing to reach a variety of destinations (medical, leisure, social, fitness), perceived daily quality of life is improved and older adults use ridehailing multiple times per month** (Saxon, 2019, Leistner, 2017). Knowledge and adoption of ridehailing is correlated with younger age, male gender, higher education, higher income (Mitra et al, 2019, Vivoda et al, 2018). However, once ridehailing is adopted, middle elderly, less educated, carless are more likely to be frequent users (Mitra et al, 2019).

- **Ridehailing knowledge and use differences by race requires more study.** A study of older adults (Vivoda, 2018) did not find a difference in ridehailing knowledge, use, or future expectations by race, but noted that Black older adults are more likely to reduce and stop driving than older White adults.

02. Microtransit Use by Older Adults

- **Microtransit features such as on-demand booking and real-time travel updates can improve mobility for older adults compared to paratransit or dial-a-ride services that typically require advanced booking.** Improved routing technology and updates to the driver about individual accommodations can allow for a more comfortable and on-time ride (Simaiakis, 2020). The lower costs and efficiency of microtransit has the potential to provide mobility for older adults in suburban and rural areas where low ridership causes transit agencies to eliminate low-performing fixed transit routes (National Academies of Sciences, Engineering, and Medicine, 2019).

03. AV Potential Usage by Older Adults

- **The access to chauffeur service, or ridehail, (an AV proxy) leads older adults to take longer trips and more trips at night vs. other age groups.** In non-chauffeur weeks, the older adults drove the fewest miles, drove the least at night, but made a higher number of shorter trips. With the chauffeur service, older adults had the greatest percentage of increase in person-miles-of-travel, number of long trips and evening trips (Harb, 2018).

APPENDIX 4: OLDER ADULT NEW MOBILITY PILOTS & PROGRAMS

01. Paradise Valley Estates, Fairfield, CA (Optimus Ride)

- In 2019, Optimus Ride began a pilot of point-to-point AV shuttle service for residents and staff in Paradise Valley estates, a 55+ independent living and continuing care gated community. The shuttle service was primarily used between friends' houses and to community amenities, such as dining and community rooms. In March 2020 amid the pandemic lockdown, community amenities were shut down and Optimus Ride shifted the pilot to deliver food from the dining facilities and packages to residents' homes.

02. The Villages, San Jose (Voyage)

- In 2017, Voyage began piloting AV shuttles along a loop in The Villages, a 4,000-resident retirement community. Currently the pilot operates nine AVs, with plans to transition to door-to-door taxis service for all residents.

03. The Villages, Central Florida (Voyage)

- In 2018, Voyage began piloting Level 4 AV taxi service in The Villages, Central Florida, an 125,000-resident retirement community. Voyage has used the pilot to refine the vehicles' driving ability, key destinations, and passenger experience.

04. NewMo (Newton, MA + VIA)

- Launched Summer 2019, this pilot provides on-demand curb-to-curb or door-to-door microtransit service to a set list of destinations within Newton and some medical facilities outside the city. In the first year, NewMo carried an average of 50 older adults per day. Rides can be reserved through an app or phone call and paid with credit or a card purchased by cash or check, as well as a Veteran's taxi voucher. Those with SNAP, MassHealth, or fuel assistance qualify for a discount (Simaiakis, 2020).

05. Rapid On Demand (Grand Rapids, Michigan + VIA)

- Launched in 2019, this six-month microtransit pilot for older adults and people with disabilities tested the feasibility of on-demand ridesharing for GO!Bus riders (the city's current paratransit service). The pilot aimed to provide same-day service and improve wait times through automatically adjusted routes in response to no-shows or cancellations. Funded by the Michigan Mobility Challenge, riders paid $3.5 per ride and could schedule within 15 minutes of departure using the app or calling a dispatcher (Simaiakis, 2020).

06. On-Demand Paratransit Pilot Program (MBTA + Curb + Lyft + Uber)

- Launched in April 2019, this pilot supplements existing paratransit service (The RIDE) with subsidized on-demand WAV provided by Curb, Lyft, and Uber. The pilot aims to decrease day-of wait times, booking times, and costs for The RIDE customers and will run through September 2020.

07. Mobility On Demand Every Day (MODE, Santa Monica + Lyft)

- Launched in July 2018, MODE includes Lyft rides and a downsized Dial-A-Ride Van program for older adults. The program aims to provide high quality mobility for older adults at a lower cost to the city than traditional dial-a-ride. The majority of those who signed up for MODE as of February 2019 used the Lyft app for rides, 25 percent used a concierge/call-in service, and less than 10 percent used the mini-vans limited to people with full disabilities.

08. Freedom in Motion (Gainesville, FL + Uber)

- Launched in 2016 as a nine-month pilot, this program provides subsidized Uber rides to older adults based on income, ranging from $1-$5 per ride. The pilot was expanded from residents of a retirement home to all older adults in the city. Smartphones were provided for low-income older adults without one. According to analysis of 2016 trip data, the primary trip purpose was social-recreational, followed by shopping and work-volunteer, and more than 35 percent of those enrolled completed more than five trips per month (Leistner, 2017).

09. Michigan Mobility Challenge

- A 2018 $8 million grant initiative to address core mobility gaps for older adults, persons with disabilities and veterans across the state. Thirteen projects were funded to address the physical and technological barriers. Projects included an integrated online booking and trip payment platform for one-click paratransit services, back-end technology improvements for routing and dispatch, and development of wheelchair accessible AV prototype.

10. Lyft Grocery Access (Martha's Table + Lyft, Washington, DC)

- From January to June 2019, the pilot provided subsidized rides for low-income families and older adults living in food deserts to visit grocery stores. Older adults paid $1.50 per ride and families paid $2.5 per ride. The pilot decreased the time needed to shop for participants and expanded access to healthy food.

11. AARP Ride@50+ Program, Columbia, South Carolina; Dallas, Texas; Washtenaw County, MI (Developed by AARP Driver Safety and powered by Feonix—Mobility Rising)

- Launched in 2018, the AARP Ride@50+ Program is a pilot built on the Mobility as a Service (MaaS) framework focused on providing older adults with continued mobility as they age. The AARP Ride@50+ Program is a one-stop shop for accessing public and private transportation options, providing a single point of access to review, compare, book, and pay for local transportation alternatives, including multi-modal trips. The Program is available to people of all ages via a toll-free call center, the smartphone app, or the online booking platform.


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REFERENCES

Abraham, H., Lee, C., Brady, S., Fitzgerald, C., Mehler, B., Reimer, B., Coughlin, J. F. (2017). "Autonomous vehicles and alternative to driving: Trust, preferences, and effect of age," Proceedings of the Transportation Research Board 96th Annual Meeting. Washington, DC.

Akil, A., & Vanieva, O. (February, 2020). "Your Ride,Rredesigned: Introducing New Features That Help Make Pickups More Seamless," Uber Newsroom. https://www.uber.com/newsroom/seamless-pickups/

American Geriatrics Society. (2015). *Clinician's Guide to Assessing and Counseling Older Drivers.* https://trid.trb.org/view/1401769

Anderson, M. (June, 2019). "Mobile Technology and Home Broadband2019,". Pew Research Center, Washington, D.C. https://www.pewresearch.org/Internet/2019/06/13/mobile-technology-and-home-broadband-2019/

AVs & Increased Accessibility. Workshop Series. (May/July/September, 2019). Auto Alliance, Washington, D.C. https://autoalliance.org/wp-content/uploads/2019/10/AVs-Accessibility-Workshop-Series-Report-16OCT2019.pdf

Bezyak, J. L., Sabella, S. A., & Gattis, R. H. (2017). "Public transportation: An investigation of barriers for people with disabilities," *Journal of Disability Policy Studies,* 28(2), 52-60.

Boisjoly, G., Grisé, E., Maguire, M., Veillette, M., Deboosere, R., Berrebi, E., & El-Geneidy, A. (2018). "Invest in the Ride: A 14 year Longitudinal Analysis of the Determinants of Public Transport Ridership in 25 North American Cities," *Transportation Research Part A: Policy and Practice* 116 (October): 434–45. https://doi.org/10.1016/j.tra.2018.07.005.

Brown, A. (2018). *Ridehail Revolution: Ridehail Travel and Equity in Los Angeles.* [Doctoral Dissertation, University of California Los Angeles].

Chaiyachati KH, Hubbard RA, Yeager A, et al. (2018). "Association of Rideshare-Based Transportation Services and Missed Primary Care Appointments: A Clinical Trial," *JAMA Intern Med.* 2018;178(3):383-389. doi:10.1001/jamainternmed.2017.8336

Cicchino, J. (2015). "Why have fatality rates among older drivers declined? The relative contributions of changes in survivability and crash involvement," *Accid Anal Prev.* 2015 Oct;83:67-73. https://pubmed.ncbi.nlm.nih.gov/26219089/

Classen, S., Mason, J., Wersal, J., Sisiopiku, V., & Rogers, J. (2020). "Older Drivers' Experience With Automated Vehicle Technology: Interim Analysis of a Demonstration Study." *Frontiers in Sustainable Cities,* 2. https://doi.org/10.3389/frsc.2020.00027

Coughlin, J. (November, 2017). "Why driverless cars alone will not solve transportation in older age," Forbes. https://www.forbes.com/sites/josephcoughlin/2017/11/30/why-driverless-cars-alone-will-not-solve-transportation-in-older-age/#7fdbffe797ae

Cox, A.E. & Cicchino, J.B. (October 2020). "Continued Trends in Older Driver Crash Involvement Rates in the United States: Data through 2017-2018." Insurance Institute for Highway Safety.

Crizzle, A. M., Vrkljan, B. H., Kajaks, T., Gish, J., & Fleisig, R. (2014). "A Systematic Review of Driver Ingress and Egress Using Passenger Behicles: Considerations for Designers," *Journal of Ergonomics*, 3, 1-5. 10.4172/2165-7556.S3-005

Czaja, S. J., Boot, W. R., Charness, N., & Rogers, W. A. (2019). Designing for older adults: *Principles and creative human factors approaches.* CRC Press. Boca Raton.

Eby, D. W. , Molnar, L. J., & Stanciu, S. C. (2018). *Older Adults' Attitudes and Opinions about Automated Vehicles: A Literature Review.* (Report No. ATLAS-2018-26. Center for Advances Transportation Leadership and Safety. http://www.atlas-center.org/wp-content/uploads/2018/11/ATLAS-Report-Older-Adults-and-Autonomous-Vehicles.pdf

Edrington S, Cherrington L, Burkhardt J, et al. (2018). *Handbook for Examining the Effects of NEMT Brokerages on Transportation Coordination.* doi:10.17226/25184

Edrington S, Cherrington L, Texas A&M Transportation Institute, et al. (2018). *State-by-State Profiles for Examining the Effects of Non-Emergency Medical Transportation Brokerages on Transportation Coordination.* (April):1-111.

Emerson, S. (April, 2017). 'GoGoGrandparent' is Overcharging Seniors for Uber Rides, and Drivers are Pissed. *Vice.* https://www.vice.com/en_us/article/bmexq3/gogograndparent-startup-seniors-uber-drivers-

Faber, K., & van Lierop, D. (2020). "How will older adults use automated vehicles? Assessing the role of AVs in overcoming perceived mobility barriers," *Transportation Research Part A: Policy and Practice, 133,* 353–363. https://doi.org/10.1016/j.tra.2020.01.022

Federal Deposit Insurance Corporation [FDIC]. (2018). *2017 FDIC National Survey of Unbanked and Underbanked Households.* Retrieved from https://www.fdic.gov/householdsurvey/2017/2017report.pdf

Fitzpatrick AL, Powe NR, Cooper LS, Ives DG, Robbins JA, Enright E. (2004). "Barriers to Health Care Access Among the Elderly and Who Perceives Them.". *Am J Public Health.* 94(10):1788-1794. doi:10.2105/AJPH.94.10.1788

Fox, S. (August, 2013). "51% of U.S. Adults Bank Online." Pew Research Center, Washington, D.C. https://www.pewresearch.org/internet/2013/08/07/51-of-u-s-adults-bank-online/

Frison, A. K., Aigner, L., Wintersberger, P., & Riener, A. (2018). "Who is Generation A?: Investigating the Experience of Automated Driving for Different Age Groups." AutomotiveUI '18 Proceedings. 94–104. https://doi.org/10.1145/3239060.3239087

Ghili, S. & Kumar, V. (2020). "Spatial Distribution of Supply and the Role of Market Thickness: Theory and Evidence from Ride Sharing," *SSRN* Scholarly Paper ID 3520187. Rochester, NY: Social Science Research Network. https://papers.ssrn.com/abstract=3520187.

Gilmer, M. (2020, January). “Lime lays off dozens andpulls e-scooter service from 12 markets,”. *Mashable.* https://mashable.com/article/lime-scooter-layoffs/.

Gindrat, R. (2020, February). “3 Reasons AV Fleets Will Proliferate Private Sites First.”. *Medium.* https://medium.com/bestmile/3-reasons-av-fleets-will-proliferate-private-sites-first-ee445b4fbd98.

Gottlieb, R. (2019, March). “Better Mobility For Seniors? TNCs and the Santa Monica MODE and GoMonrovia Programs,”. *Streetsblog LA.* https://la.streetsblog.org/2019/03/20/better-mobility-for-seniors-tncs-and-the-santa-monica-mode-and-gomonrovia-programs/

Graehler Jr., M., Mucci, R. & Erhardt, G. (2019). “Understanding the Recent Transit Ridership Decline in Major U.S. Cities: Service Cuts or Emerging Modes?” University of Kentucky. https://uknow.uky.edu/research/understanding-traffic-impacts-uber-lyft-greg-erhardt.

Hall, J., Palsson, C. & Price, J. (2018). “Is Uber a substitute or complement for public transit?” *Journal of Urban Economics* 108 (November): 36–50. https://doi.org/10.1016/j.jue.2018.09.003.

Harb, M., Xiao, Y., Circella, G., Mokhtarian, P. L., & Walker, J. L. (2018). “Projecting travelers into a world of self-driving vehicles: Estimating travel behavior implications via a naturalistic experiment,” *Transportation, 45*(6), 1671–1685. https://doi.org/10.1007/s11116-018-9937-9

Herriotts, P. (2005). “Identification of vehicle design requirements for older drivers,” *Applied Ergonomics,* 36, 255-262. 10.1016/j.apergo.2005.01.002

Huff Jr, E. W., DellaMaria, N., Posadas, B., & Brinkley, J. (2019, October). “Am I Too Old to Drive? Opinions of Older Adults on Self-Driving Vehicles, “ The 21st International ACM SIGACCESS Conference on Computers and Accessibility (pp. 500-509). https://doi.org/10.1145/3308561.3353801

Jiang, J. (January, 2019). “More Americans are using ride-hailing apps,”. Pew Research Center, Washington, D.C. https://www.pewresearch.org/fact-tank/2019/01/04/more-americans-are-using-ride-hailing-apps/

Jin, S., Kong, H. & Sui, D. (2019). “Uber, Public Transit, and Urban Transportation Equity: A Case Study in New York City,” *The Professional Geographer* 71 (2): 315–30. https://doi.org/10.1080/00330124.2018.1531038.

Joseph, R. (2018, August). “Ride-Sharing Services: The Tumultuous Tale of the Rural Urban Divide,” AMCIS 2018 Proceedings. https://aisel.aisnet.org/amcis2018/AdoptionDiff/Presentations/4.

Kajaks, T., Crizzle, A., Gish, J., Fleisig, R., & Vrkljan, B. (2015). *“Older adults and vehicle design: Evidence-based approach to examining vehicle ingress and egress.”* Proceedings of the Human Factors and Ergonomics Society 59th Annual Meeting, 1656-1660.

König, M. & Neumayr, L. (2017). “Users’ resistance towards radical innovations: The case of the self-driving car.” *Transportation Research Part F, 44,* 42-52.

Lam, C., Liu, M, & Hui, X. (2020). "The Geography of Ridesharing: A Case Study of New York City," *SSRN* Scholarly Paper ID 2997190. Rochester, NY: Social Science Research Network. https://papers.ssrn.com/abstract=2997190.

LaRosa, M, & Bucalo, S, "Inclusive Shared Mobility: Enabling Service for Older Adults and People with Disabilities," Prepared for National Aging and Disability Transportation Center, Shared Mobility Inc., All Rights Reserved, March 2020.

Leistner, D. L., & Steiner, R. L. (2017). "Uber for Seniors?: Exploring Transportation Options for the Future," *Transportation Research Record, 2660*(1), 22–29. https://doi.org/10.3141/2660-04

Lekach, S. (n.d.). "It's hard to get a wheelchair-accessible Lyft or Uber in most places. Here's why," Mashable. Retrieved July 20, 2020, from https://mashable.com/article/lyft-uber-wheelchair-accessible/

Lynott, L. (2018). *Universal Mobility as a Service: A Bold Vision for Harnessing the Opportunity of Disruption.* AARP Public Policy Institute. https://www.aarp.org/content/dam/aarp/ppi/2018/08/universal-mobility-as-a-service-aarp-ppi.pdf

Mitman, M.F., Davis, S., Bullus Armet, I., & Knopf, E. (n.d.) *Curbside Management Practitioners Guide.* Institute of Transportation Engineers.

Mejia, J., & Parker, C. (2020). "When Transparency Fails: Bias and Financial Incentives in Ridesharing Platforms,". *Management Science.* Advanced online publication. https://doi.org/10.1287/mnsc.2019.3525

Mitra, S. K., Bae, Y., & Ritchie, S. G. (2019). "Use of Ride-Hailing Services among Older Adults in the United States," *Transportation Research Record, 2673*(3), 700–710. https://doi.org/10.1177/0361198119835511

Motavalli, J. (2020, May). "Who Will Own the Cars That Drive Themselves?" *The New York Times,* https://www.nytimes.com/2020/05/29/business/ownership-autonomous-cars-coronavirus.html.

NACTO. (2017, November). *Curb Appeal: Curbside management strategies for improving transit reliability.* https://nacto.org/wp-content/uploads/2017/11/NACTO-Curb-Appeal-Curbside-Management.pdf

NADTC. (2017). *Shared Ride Services and Transportation Network Companies.* https://www.nadtc.org/wp-content/uploads/NADTC-Trends-Report-Shared-Ride-Topic-Spotlight-May-2017.pdf

National Academies of Sciences, E. (2019). *Microtransit or General Public Demand–Response Transit Services: State of the Practice.* https://doi.org/10.17226/25414

National Center for Mobility Management [NCMM]. (June, 2018). *Autonomous Vehicles: Considerations for People with Disabilities and Older Adults.* https://nationalcenterformobilitymanagement.org/wp-content/uploads/2018/08/AVs_PwD_OA_Final_sm.pdf

O'Hara, Amy (April 2020). "Unlocking Mobility Equity through Integrated Payment Systems." State of Transportation Planning 2020: Moving People Over Cars: Mobility for Healthy Communities, American Planning Association: Transportation Planning Division.

Okoro CA, Strine TW, Young SL, Balluz LS, Mokdad AH. (2005). "Access to health care among older adults and receipt of preventive services," Results from the Behavioral Risk Factor Surveillance System, 2002. *Prev Med (Baltim);* 40(3):337-343.

Payyanadan, R. & Lee, J. "Understanding the ridesharing needs of older adults,". *Travel Behavior and Society* 13:155-164.

Peck, M. D. (June, 2010). *Barriers to using fixed-route public transit for older adults* [Report]. Mineta Transportation Institute. https://rosap.ntl.bts.gov/view/dot/18349

Pierson, D. (2017, August). "Lyft now picks up anywhere in 40 states, grabbing areas Uber doesn't cover,". *Los Angeles Times.* https://www.latimes.com/business/la-fi-lyft-uber-statewide-20170831-story.html.

Powers B, Rinefort S, Jain SH. (2018). "Shifting Non-Emergency Medical Transportation To Lyft Improves Patient Experience And Lowers Costs." *Heal Aff Blog.* 1-9. doi:10.1377/hblog20180907.685440

Raphael, R. (2019, October). "How free Lyft rides can dramatically improve life for senior citizens," *Fast Money.*

S., T. (2018, March). "Why driverless cars will mostly be shared, not owned,". *The Economist,* March 5, 2018. https://www.economist.com/the-economist-explains/2018/03/05/why-driverless-cars-will-mostly-be-shared-not-owned.

Saxon, L., Ebert, R., & Sobhani, M. (2019). "Health Impacts of Unlimited Access to Networked Transportation in Older Adults," *The Journal of mHealth.* https://thejournalofmhealth.com/health-impacts-of-unlimited-access-to-networked-transportation-in-older-adults/

Schaller, B. (2018). *The New Automobility: Lyft, Uber and the Future of American Cities.* Schaller Consulting. http://www.schallerconsult.com/rideservices/automobility.htm.

Schlossberg, M., Riggs, W., Millard-Ball, A., & Shay, E. (2018, January). *Rethinking the Street in an Era of Driverless Cars.* University of Oregon. https://cpb-us-e1.wpmucdn.com/blogs.uoregon.edu/dist/f/13615/files/2020/01/RethinkingtheStreet.pdf

Secter, B., & Bordens, A. (2013, July). "Divvy opens strong in white neighborhoods," *Chicago Tribune.* https://www.chicagotribune.com/news/ct-xpm-2013-07-10-ct-met-divvy-bike-location-20130710-story.html

SFMTA. (2019). *TNCs and Disabled Access.* https://www.sfmta.com/sites/default/files/reports-and-documents/2019/05/tncs_and_disabled_access_report.pdf

Shaheen, S. & Chan, N. (2016). "Mobility and the Sharing Economy: Potential to Overcome First- and Last-Mile Public Transit Connections," *UC Berkeley Transportation Sustainability Research Center.* https://doi.org/10.7922/G2862DN3.

Short, A. (2019, October). "Post-Mortem: Car2Go Is Car2Gone in 5 Cities." *Streetsblog USA.* https://usa.streetsblog.org/2019/10/01/post-mortem-car2go-is-car2gone-in-5-cities/.

Simaiakis, Y. (2020). "Cities Ready to Modernize Paratransit May Have a New Solution," *Institute of Transportation Engineers. ITE Journal; Washington, 90*(6), 37–42.

Snellgrove, CA. *Cognitive Screening for the Safe Driving Competence of Older People with Mild Cognitive Impairment or Early Dementia.* Canberra; 2005.

Souders, D. J., & Charness, N. (2016). "Challenges of older drivers' adoption of advanced driver assistance systems and autonomous vehicles.". In: *International Conference on Human Aspects of IT for the Aged Population,* pp.428-440. Springer.

Span, P. (2019, August). "Older People Need Rides. Why Aren't They Using Uber and Lyft?" *The New York Times.* https://www.nytimes.com/2019/08/16/health/uber-lyft-elderly.html

Stocker, A., & Shaheen, S. (2017). "Shared Automated Vehicles: Review of Business Models.2017–09,". International Transportation Forum Roundtable on Cooperative Mobility Systems and Automated Driving. https://www.itf-oecd.org/sites/default/files/docs/shared-automated-vehicles-business-models.pdf.

The Hartford. (2015). *In the driver's seat: a guide to vehicle safety technology.* https://s0.hfdstatic.com/sites/the_hartford/files/vehicle-technology.pdf

The Pew Charitable Trusts. (October, 2019). "Are Americans embracing mobile payments?" https://www.pewtrusts.org/en/research-and-analysis/issue-briefs/2019/10/are-americans-embracing-mobile-payments#:~:text=Although%2088%20percent%20of%20Americans,linked%20to%20a%20mobile%20platform.

Tooley, M., Zmud, J., Ettelman, B., Moran, M., Higgins, L., Shortz, A., & Wheeler, E. (2019). *Older Drivers and Transportation Network Companies: Investigating Opportunities for Increased Safety and Improved Mobility* [Report]. Safe-D: Safety Through Disruption. https://vtechworks.lib.vt.edu/handle/10919/95179

Vivoda, J. M., Harmon, A. C., Babulal, G. M., & Zikmund-Fisher, B. J. (2018). "E-hail (rideshare) knowledge, use, reliance, and future expectations among older adults," *Transportation Research Part F: Traffic Psychology and Behaviour, 55,* 426–434. https://doi.org/10.1016/j.trf.2018.03.020

Vogels, E. (September, 2019). "Millennials stand out for their technology use, but older generations also embrace digital life," Pew Research Center, Washington, D.C. https://www.pewresearch.org/fact-tank/2019/09/09/us-generations-technology-use/

Wakabayashi, D. (2017, October). "Where Driverless Cars Brake for Golf Carts," *The New York Times.* https://www.nytimes.com/2017/10/04/technology/driverless-cars-testing.html

Wang, M., & Mu, Lan. (2018). "Spatial Disparities of Uber Accessibility: An Exploratory Analysis in Atlanta, USA," *Computers, Environment and Urban Systems* 67 (January): 169–75. https://doi.org/10.1016/j.compenvurbsys.2017.09.003.

Ward, C., Raue, M., Lee, C., D'Ambrosio, L., & Coughlin, J. F. (2017). "Acceptance of automated driving across generations: The role of risk and benefit perception, knowledge, and trust," M. Kurosu (Ed.). HCI 2017, Part I, LNCS 10271, pp. 254-266. *Springer International Publishing.* 10.1007/978-3-319-58071-5_20

When and Where Is Uber Available in My City? Uber. Accessed August 5, 2020. https://help.uber.com/riders/article/when-and-where-is-uber-available-in-my-city?nodeId=558929fa-b991-4810-b6db-8c823862d7d4.

Young, M., Allen, J. & Farber, S. (2020). "Measuring When Uber Behaves as a Substitute or Supplement to Transit: An Examination of Travel-Time Differences in Toronto," *Journal of Transport Geography* 82: 102629.

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