TCRP
Research Report 244

Transit Cooperative
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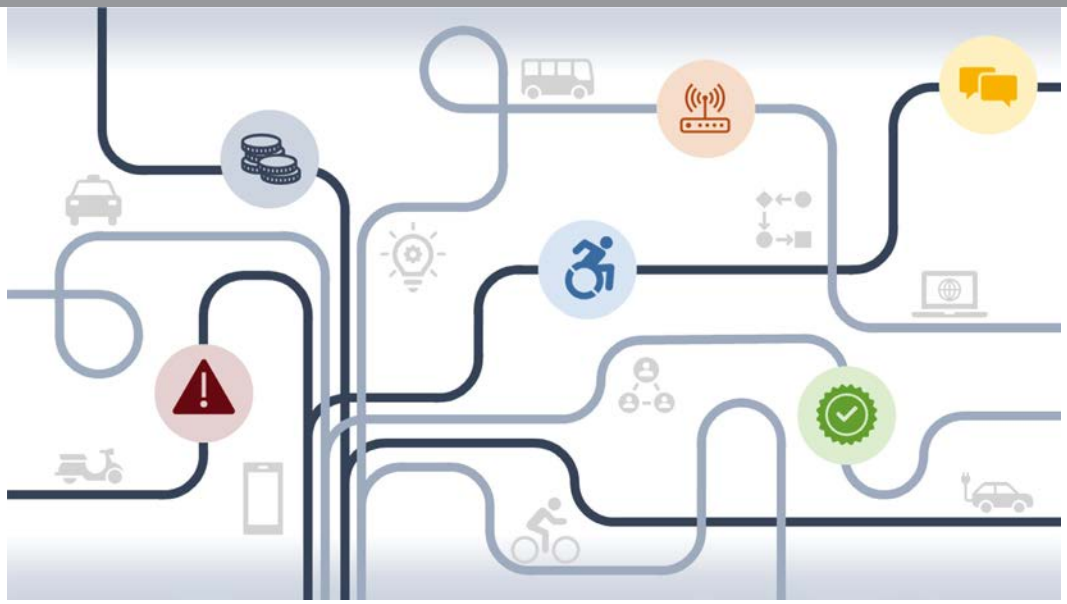
NCHRP
Research Report 1101

National Cooperative
Highway Research
Program

Transformational Technologies and Mobility Inclusion Playbook

JOINT REPORT



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TRANSIT COOPERATIVE RESEARCH PROGRAM

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP RESEARCH REPORT 1101

Transformational Technologies and Mobility Inclusion Playbook

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Public Transportation • Planning and Forecasting

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, adapt appropriate new technologies from other industries, and introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000,* also recognized the need for local, problem-solving research. TCRP, modeled after the successful National Cooperative Highway Research Program (NCHRP), undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes various transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA; the National Academies of Sciences, Engineering, and Medicine, acting through the Transportation Research Board (TRB); and APTA. APTA is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Commission.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Commission to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Commission defines funding levels and expected products.

Once selected, each project is assigned to an expert panel appointed by TRB. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired effect if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

TCRP provides a forum where transit agencies can cooperatively address common operational problems. TCRP results support and complement other ongoing transit research and training programs.

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed, and implementable research is the most effective way to solve many problems facing state departments of transportation (DOTs) administrators and engineers. Often, highway problems are of local or regional interest and can best be studied by state DOTs individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation results in increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

Recognizing this need, the leadership of the American Association of State Highway and Transportation Officials (AASHTO) in 1962 initiated an objective national highway research program using modern scientific techniques—the National Cooperative Highway Research Program (NCHRP). NCHRP is supported on a continuing basis by funds from participating member states of AASHTO and receives the full cooperation and support of the Federal Highway Administration (FHWA), United States Department of Transportation, under Agreement No. 693JJ31950003.

The Transportation Research Board (TRB) of the National Academies of Sciences, Engineering, and Medicine was requested by AASHTO to administer the research program because of TRB's recognized objectivity and understanding of modern research practices. TRB is uniquely suited for this purpose for many reasons: TRB maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; TRB possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; TRB's relationship to the National Academies is an insurance of objectivity; and TRB maintains a full-time staff of specialists in highway transportation matters to bring the findings of research directly to those in a position to use them.

The program is developed on the basis of research needs identified by chief administrators and other staff of the highway and transportation departments, by committees of AASHTO, and by the FHWA. Topics of the highest merit are selected by the AASHTO Special Committee on Research and Innovation (R&I), and each year R&I's recommendations are proposed to the AASHTO Board of Directors and the National Academies. Research projects to address these topics are defined by NCHRP, and qualified research agencies are selected from submitted proposals. Administration and surveillance of research contracts are the responsibilities of the National Academies and TRB.

The needs for highway research are many, and NCHRP can make significant contributions to solving highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement, rather than to substitute for or duplicate, other highway research programs.

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The **Transportation Research Board** is one of seven major program divisions of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to mobilize expertise, experience, and knowledge to anticipate and solve complex transportation-related challenges. The Board's varied activities annually engage about 8,500 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

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The research team would like to extend its appreciation to various transportation agencies, advocacy and social services organizations, technology providers, and other agencies and organizations that have deployed, are in the process of deploying, or are planning to deploy shared automated vehicles. We sincerely thank them for generously donating their time and sharing their experiences. A list of stakeholders interviewed is provided in Appendix B.

We are also deeply grateful to the focus group and survey participants for their support and involvement, which resulted in providing invaluable insights for the development of this playbook.

This playbook represents the culmination of a true collaboration with all our partners and is intended to support various agencies and organizations in making a meaningful impact through inclusive transportation systems that enhance mobility, equity, and access for all.

FOREWORD

By Gwen Chisholm Smith
Staff Officer
Transportation Research Board

TCRP Research Report 244/NCHRP Research Report 1101: Transformational Technologies and Mobility Inclusion Playbook is a playbook of resources for public and private entities to assess, plan, and measure their progress toward achieving transportation equity and inclusive mobility in an era of transformational technology. It focuses on specific technologies and how their benefits can widen accessibility gaps for the underserved and the consequences for travelers and others who are not direct users of these technologies. This report will be of immediate use to transportation policymakers and decision-makers at planning organizations, transit agencies, and other transportation entities involved with data analysis on the impacts of new technologies on travel behavior. The playbook will also aid practitioners in efforts to include underserved users in the transportation technology revolution.

Changes in technology provide opportunities and risks to mobility, particularly as they relate to traditionally and newly underserved populations. In recent years, economic, environmental, and social forces have quickly given rise to shared and on-demand mobility—a collective of entrepreneurs and consumers leveraging technology to maximize transportation and financial resources and generate capital. For instance, shared mobility services have become part of a trend that has pushed shared, on-demand mobility from the fringe into the mainstream. These services have included micromobility options, such as electric scooters and bikesharing in various forms (station-based systems, dockless systems, and bikes that are traditional or electric-assist). Car-based services have included carsharing with either station-based or one-way service models; ride-hailing services; and peer-to-peer carsharing services.

The research was conducted by the Texas A&M Transportation Institute (TTI), EBP US, and GO Systems and Solutions LLC. The playbook was developed as the lead research product from TCRP Project B-47, "Impact of Transformational Technologies on Underserved Populations." NCHRP Project 20-102(30), "Equity Impacts of Shared AVs on Transportation-Disadvantaged Communities," leveraged and informed the work on the playbook.

This project developed a playbook that contains guidance on corrective actions that include data, methods, and metrics to achieve inclusive mobility.

The playbook begins with an overview of the transformational technologies. It also provides definitions of the transformational technologies; describes five underserved populations that were the primary focus of this study; describes how to use the playbook; presents 10 transformational technology plays; and offers implementation considerations.

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A-1 **Appendix A** Literature Review

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SUMMARY

Transformational Technologies and Mobility Inclusion Playbook

As an integral component of the evolving transformative transportation ecosystem, it is of utmost importance to prioritize the promotion of new and future mobility services that cater to the needs of all populations. This commitment ensures equitable access and transportation options for individuals across diverse socioeconomic backgrounds, geographic locations, physical abilities, and so forth. By embracing inclusive approaches, agencies can foster a comprehensive and accessible transportation network that leaves no one behind. These concepts and approaches can be applied in a variety of settings to ensure the equitable implementation of new services.

Several barriers pose challenges for individuals to access and use these new mobility services. The key barriers include limited availability; restricted access to technology; lack of awareness; inadequate accessibility; and concerns regarding safety, security, and affordability of these services. Addressing these barriers is essential to ensure equitable access and meaningful participation in the transformative transportation landscape and requires proactive efforts, collaboration, and innovative solutions. Acknowledging the complexities involved in achieving equitable access to new mobility services, *TCRP Research Report 244/ NCHRP Research Report 1101: Transformational Technologies and Mobility Inclusion Playbook* (the playbook) provides a practical guide for addressing barriers to accessing transformational transportation technologies and deploying these technologies in an inclusive manner. It concentrates on what needs to be done and for whom.

The playbook was created under two projects: TCRP Project B-47, "Impact of Transformational Technologies on Underserved Populations," and NCHRP Project 20-102(30), "Equity Impacts of Shared AVs on Transportation Disadvantaged Communities." The researchers analyzed available literature, interviewed stakeholders, and conducted surveys and focus groups to identify the barriers to accessing these transformational technologies for historically underserved populations and strategies to build the capacity to fill gaps in key population needs.

This playbook was developed to support transit agencies, transportation planning organizations, mobility providers, state departments of transportation (DOTs), and other organizations that want to provide safe, fair, and accessible (public) transportation tailored to the needs of underserved populations. It covers a collection of strategies—aimed to help users develop an action plan based on their needs—that address three dimensions:

- **Goal.** The primary goal that organizations seek to achieve in a particular underserved community. The following goals are considered in this playbook: availability, access to technology, awareness, accessibility, safety and security, and affordability.
- **Service.** The target transformational technology to achieve the identified goal in the underserved community. The services considered within the playbook include app-based

carpooling services, bikesharing services, carsharing services, e-scooter sharing services, ridehailing services, and fully automated vehicle services, with a focus on shared services.
- **Population.** The target underserved community for which solutions are desired to increase the use of and access to the technology identified. Consistent with the scope of this project, the playbook primarily focuses on the following population groups: people aged 65 years or older, people who speak little or no English, people with disabilities, people with low incomes, and people residing in rural areas or on tribal reservations.

While there is a specific focus on transformational technologies and underserved populations, the information, tools, and strategies presented in this playbook are transferable and should be considered when addressing the needs of new services or other population groups. The inherent flexibility and adaptability of the plays enable them to be customized and tailored to diverse contexts, ensuring that the playbook retains its value as a resource for a wide range of stakeholders.

This playbook describes scenarios that address specific barriers to accessing transformational technologies by recommending promising strategies to help mitigate the obstacles to use. Each scenario is a formal "play" to help reduce gaps or mitigate barriers to specific transformational technologies that are experienced by underserved communities. The playbook consists of 10 plays, each encompassing an overview of the play, the barriers associated with it, and strategies for overcoming those barriers.

Emerging technologies are typically deployed in high return-on-investment (ROI) environments, but there is a growing need to prioritize underserved communities to achieve a balance between feasibility and equitable distribution. This is not an easy task and requires consideration of several key questions. The playbook provides insights into such implementation-related questions (including duration and cost) and provides a checklist related to the following focus areas:

- **Defining Overall Program Needs.** In the effort to eliminate barriers to accessing transformational technologies, having a clear understanding of the intent of the service and the boundaries within which it is operating is essential. This understanding must be gained through the perspectives of those being served and in the context of what can be achieved with available resources. This step cannot be bypassed even by those with the most earnest of intentions and must be a key part of the implementation policy in every case.
- **Communicating and Adapting with the Target Population.** One of the biggest hurdles to overcome is communicating with an underserved population. It is key for the success of the program to open this line of communication in a way that is comfortable and conducive to learning the community's real needs. As transportation providers or practitioners, it might seem easy or reasonable to assume the needs of travelers and where people want to go. Transportation needs must be viewed through the eyes of the participants for their true needs to be properly defined. In cases of success or failure, as well as during negative events, it is crucial to establish clear and transparent communication channels as part of the response. Agencies approach these projects with the intention of success but must also prepare for potential challenges or negative outcomes. It is critical to communicate the complete story to foster confidence and garner support.
- **Assessing Funding Approaches.** Funding scenarios for these programs can be complicated depending on the role public agencies and private companies take in planning and deployment. Decisions about public- or private-sector lead should be carefully weighed.
- **Maintaining Compliance.** Funding for these programs can come with strict requirements and recordkeeping. The implementor must be able to demonstrate attention to detail to ensure compliance. Having a plan to meet all the requirements before the operation begins is essential.

- **Evaluating Vehicle Autonomy.** As a still-developing technology that stands to offer a massive change to transportation, automated vehicles (AVs), including shared AVs, must be assessed for their ability to respond to current transportation gaps and barriers.
- **Exploring Private-Sector Implications.** The implementation of transformational technologies by private-sector entities gravitates to the locations and services with the greatest efficiency and highest return first. These decisions can limit access to these services, and the greatest impact is felt by those with limited means and those with accessibility limitations. The increasing sophistication of transformational technologies also provides opportunities to facilitate broader access.
- **Examining Other Factors.** There are some challenges facing the implementation of transformative technologies that are particularly difficult to overcome or are far beyond the ability of the implementing agency to control or influence.

It is essential to emphasize that the implementation of the outlined steps will not only promote fairness and equity but also significantly enhance the lives of people from underserved communities and others. For example, currently, paratransit and other scheduled ride services can be inconvenient and challenging to use, particularly for new or occasional users who must schedule their trips a day in advance and face uncertain pickups. However, by overcoming these barriers and providing more flexible transportation options, agencies can make a tangible difference in the quality of life for underserved individuals.

CHAPTER 1

Introduction

Transformational technologies in transportation have made transportation choices more convenient and broadly available by enabling shared, on-demand mobility services. These services, ranging from micromobility options to car-based services and ridehailing platforms, have gained significant popularity and have become mainstream. Similarly, future mobility services (including the future implementation of shared AVs) expand the realm of shared mobility options by incorporating automation into various transportation modes, such as microtransit, on-demand, and taxi services.

However, these technologies have not necessarily made travel choices more accessible or inclusive for all people. Although these services offer numerous benefits, lack of access to—and exclusion from—new mobility services exacerbates the social inequities faced by historically marginalized and underserved populations, such as people with low incomes, people with disabilities, and people who live in rural areas or on tribal reservations. Failure to address the needs of these populations in transportation planning can perpetuate historical, institutional disenfranchisement.

For example, limited service availability restricts the geographic reach of new mobility options, as in the case of limited availability of services in rural and tribal areas, where transportation options are scarce, leaving these communities further marginalized. Another significant barrier is unequal access to technology, such as smartphones or internet connectivity, which hinders individuals' ability to use these services. Low awareness among underserved populations about the existence and benefits of new mobility options further limits their uptake. Accessibility barriers, both physical and digital, create challenges for individuals with disabilities or limited mobility to fully engage with and benefit from these services. Safety and security concerns, such as unease about personal safety during rides and lack of trust in AVs, can deter individuals from embracing new mobility solutions. Affordability also remains a critical barrier, with cost considerations impacting the access and usage of these services, particularly for people with low incomes. Such barriers disproportionately impact underserved populations, exacerbating existing transportation disparities.

To ensure equity of transport systems, policies and regulatory actions should start by considering people and their needs rather than technologies and their potential benefits. Mobility by definition needs to get people where they want to go when they want to get there. Mobility inclusion is not an impact but a goal, and the role of government is to promote and facilitate the adoption of new mobility solutions that meet the needs and aspirations of all people in a community. The vehicle design and technologies used, the markets addressed, and the regulations imposed on new mobility services and technologies are all factors that may exert a strong influence over how mobility enhancements are distributed.

This playbook presents solutions for the successful implementation of transformative transportation technologies in a fair and equitable manner. Through the process of identifying goals, barriers, and strategies, the user can plan and implement a successful program that leaves no one behind.

Study Overview

The level of inclusivity of travel is determined by the ease of reaching and interacting with destinations. The level of inclusivity is higher if the service provides access to all population segments in a service coverage area. Certainly, some barriers to access and inclusivity, such as geographic availability of service, have always existed, and despite the introduction of transformational technologies, these barriers still need to be addressed. However, new barriers have been either introduced or reinforced by new mobility. These latter barriers are the ones that this playbook was created to address.

This study included several tasks leading up to the pinnacle task of creating the playbook. The following research questions guided the study:

1. To what degree and for what purposes are underserved populations using new mobility options, if at all? What factors prevent their access and use? What factors facilitate their access and use?
2. How are specific populations excluded from new mobility services? What does an individual need to have to access them?
3. Are there cities or other jurisdictions implementing new mobility services in which mobility inclusion has been a stated policy goal? What policies or regulations have facilitated this goal? What policies or regulations have hindered this goal? What metrics have been used to measure progress toward this goal?
4. In what ways has the lack of infrastructure hindered access and use of new mobility options, and in what ways will this lack hinder access and use in the future? What infrastructure-specific policies or regulatory strategies have been implemented (or attempted) to achieve mobility inclusion? What elements of a successful business model (or at least one appealing to drivers) are limiting a broader implementation?
5. What does it take for everyone to access the services/technologies? How is it different for different populations?
6. For each of the previous, how does the introduction of vehicle automation alter the impacts (positive or negative) of transformational technologies? How are these impacts different for different populations?

The following two projects were involved in the creation of the playbook:

- TCRP Project B-47, "Impact of Transformational Technologies on Underserved Populations," in which the researchers analyzed available literature, performed a gap analysis, interviewed stakeholders, and conducted surveys and focus groups with historically underserved populations for the new mobility services considered as part of this project.
- NCHRP Project 20-102(30), "Equity Impacts of Shared AVs on Transportation Disadvantaged Communities," which involved analysis of available literature and interviews with stakeholders, providing a more detailed examination of shared AVs as emerging mobility services.

Details on those initial tasks are presented in the appendices as follows:

- **Appendix A: Literature Review.** Separate literature reviews were conducted for TCRP Project B-47 and NCHRP Project 20-102(30) to answer the research questions and guide the direction and completion of all other tasks.

- **Appendix B: Stakeholder Interviews.** Separate stakeholder interviews were conducted for TCRP Project B-47 and NCHRP Project 20-102(30) to better understand how current mobility services or future shared AV deployments incorporate equity considerations, with special attention being paid to gaining diverse perspectives from a variety of stakeholders.
- **Appendix C: Underserved Population Focus Groups.** Online focus groups were conducted as part of TCRP B-47 to elicit information to aid in finalizing online survey questions that provided keen insights into the travel behaviors and preferences of underserved populations. Additional focus groups were conducted as part of NCHRP 20-102(30) to gain insights into challenges and opportunities associated with shared AV services.
- **Appendix D: Underserved Population Survey.** An online survey was employed as part of TCRP B-47 to gather information from members of underserved populations about their use of new mobility services, existing barriers to use, and potential solutions.

Appendices B–D are available on the National Academies Press website (nap.nationalacademies.org) by searching for *TCRP Research Report 244/NCHRP Research Report 1101: Transformational Technologies and Mobility Inclusion Playbook*.

The findings from both projects were then used to identify the barriers to accessing the transformational technologies for historically underserved populations and strategies that filled gaps in key population needs. Following is a brief description of each of the primary topics of interest that guided the study tasks and shaped the playbook.

Transformational Technologies

According to *NCHRP Research Report 924: Foreseeing the Impact of Transformational Technologies on Land Use and Transportation,* transformational technologies are any of a broad range of evolving new applications of science, engineering, and societal organization that have the potential to transform how people and institutions use land and transportation systems to support economic and social activity (Kittelson & Associates, Inc. et al. 2019). Transformational technologies have made transportation choices more convenient and broadly available by enabling shared, on-demand mobility. Eventually, on-demand transportation will be transformed to include automated mobility as well.

For this study, and consistent with the scope of the project, the transformation technologies considered for the development of this playbook focused on the following mobility services:

- App-based carpooling services.
- Bikesharing services.
- Carsharing services.
- E-scooter sharing services.
- Ridehailing services.
- Fully automated vehicle services, with a focus on shared AV services.

Table 1 provides definitions for each of the transformational technologies.

Transportation is a dynamic and ever-evolving field, shaped by changing technologies and shifting community needs. Throughout this project, the research team witnessed the emergence of various innovative transportation modes. For example, while microtransit is not a new concept, recent developments in app-based services have influenced how people access and use such services. These developments have underscored the importance of adaptable strategies in this playbook. The researchers anticipate that the **strategies developed in this playbook will not only benefit the transformation technologies considered within the scope of this project but also remain relevant to the continuously evolving landscape of transportation**, including emerging modes like app-based microtransit services.

Table 1. Definitions of transformational technologies used in the playbook.

Transformational Technology	Definition	Reference
App-Based Carpooling Services	A concurrently shared commercial ride service in a motor vehicle where the traveler is matched with other riders traveling along a similar or identical route using a digitally enabled application or platform (e.g., smartphone apps).	SAE International/ISO, June 2021, Taxonomy of On-Demand and Shared Mobility: Ground, Aviation, and Marine.
Bikesharing Services	A service that provides travelers on-demand, short-term access to a shared fleet of bicycles, usually for a fee. Bikesharing service providers may own, maintain, and provide charging (if applicable) for the bicycle fleet. Bikesharing includes pedal-only and powered bicycles such as e-bikes. Bikesharing is a form of shared micromobility.	SAE International/ISO, June 2021, Taxonomy of On-Demand and Shared Mobility: Ground, Aviation, and Marine.
Carsharing Services	A service that provides travelers on-demand, short-term access to a shared fleet of motor vehicles typically through a membership, and the traveler pays a fee for use. Carsharing service providers typically own and maintain the vehicle fleet and provide insurance, gasoline/charging, and parking.	SAE International/ISO, June 2021, Taxonomy of On-Demand and Shared Mobility: Ground, Aviation, and Marine.
E-scooter Sharing Services	A service that provides travelers on-demand, short-term access to a shared fleet of scooters for a fee. E-scooter-sharing service providers typically own, maintain, and provide fuel/charging (if applicable) for the scooter fleet. Service providers may also provide insurance. Scooter sharing includes standing and seated scooters that are solely human-powered and those that are partially or fully powered by a motor or engine. Scooter sharing is a form of shared micromobility.	SAE International/ISO, June 2021, Taxonomy of On-Demand and Shared Mobility: Ground, Aviation, and Marine.
Ridehailing Services	A service that provides travelers with prearranged and/or on-demand access to a ride for a fee using a digitally enabled application or platform (e.g., smartphone apps) to connect travelers with drivers using their personal, rented, or leased motor vehicles. Digitally enabled applications are typically used for booking, electronic payment, and ratings. Ridehailing service, also known as ridesourcing or transportation network company (TNC), refers to a type of for-hire ride service. These terms are often used interchangeably. A shared TNC ride service is usually referred to as ridesplitting or ridepooling.	SAE International/ISO, June 2021, Taxonomy of On-Demand and Shared Mobility: Ground, Aviation, and Marine.
Fully Automated Vehicle Services	A service that includes sustained and unconditional (i.e., not operating design domain-specific) performance by an automated driving system of the entire dynamic driving task and fallback (SAE Level 5: Full Driving Automation). This technology could be applied to other services, for instance, ridehailing services or microtransit services, in which an SAE Level 5 vehicle is used.	SAE International, April 2021, SAE J3016: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles.

Underserved Populations

Significant gaps exist in people's ability to use transformational technologies in transportation. Age, race, gender, income, ethnicity, and ableness are all factors that have historically influenced personal mobility. People may also be underserved because of geography, including rural isolation, redlining and urban renewal, and access to necessary communication and payment methods. Now, even with the emergence of new travel modes and technologies, certain population segments are still systematically excluded.

The development of this playbook focused on addressing the needs of underserved groups, with a particular emphasis on the following population segments:

- People aged 65 years or older.
- People who speak little or no English.
- People with disabilities (including hearing disabilities, ambulatory disabilities, vision disabilities, and cognitive disabilities).
- People with low incomes.
- People residing in rural areas or on tribal reservations.

According to the U.S. Census American Community Survey (ACS), of the U.S. population in 2021, 12% lived below the poverty level; 13% had one or more disabilities (4% with hearing, 7% with ambulatory, 3% with vision, and 5% with cognitive disabilities); 17% were 65 years old or older; 4% identified their ability to speak English as either not well or not at all; 17% resided in rural areas; and 2% were Indigenous (U.S. Census Bureau 2021).

Additional factors that limit underserved populations from participating in emerging mobility services include a lack of access to credit cards and the banking system. According to the 2021 Federal Deposit Insurance Corporation (FDIC) National Survey of Unbanked and Underbanked Households, 28.5% of households did not have a credit card. Moreover, 4.5% were unbanked, and 14.5% were underbanked, with much higher rates among marginalized communities. [Underbanked refers to households that were banked "and in the past 12 months used at least one of the following nonbank transaction or credit products or services that are disproportionately used by unbanked households to meet their transaction and credit needs: money orders, check cashing, or international remittances (i.e., nonbank transactions) or rent-to-own services or payday, pawn shop, tax refund anticipation, or auto title loans (i.e., nonbank credit)" (FDIC 2021). On the other hand, unbanked means "no one in the household had a checking or savings account at a bank or credit union (i.e., bank)" (FDIC 2021)]. For example, the study findings noted that "unbanked rates were higher among lower-income households, less-educated households, Black households, Hispanic households, working-age households with a disability, and single-mother households" (FDIC 2021).

This playbook can serve as a valuable resource for those seeking to address the diverse needs of a broader range of populations and foster more inclusive and equitable services and support systems.

Although this playbook focuses specifically on the five population segments listed previously, **the information, tools, and strategies developed can be applied and expanded to other underserved groups, accommodating the unique needs and challenges that arise from the intersections of various social identities.**

The concept of intersectionality is significant to acknowledge because it greatly expands the applicability of the playbook. According to Bauer et al. (2021), "Intersectionality is a theoretical framework wherein consideration of heterogeneity across different intersections of social positions is integral to understanding health and social experiences." Intersectionality recognizes that individuals may simultaneously belong to multiple marginalized groups, resulting in compounded forms of discrimination and disadvantages. This concept provides a valuable framework for understanding how differences in one's identity and their intersections with other identities can influence transportation uptake (Yuan et al. 2023).

Following are some examples of how the plays developed for the specific population segments could be adapted to meet the needs of other underserved groups.

- **People of Color.** While this playbook does not specifically address the unique challenges faced by communities of color, some of the strategies could be applied to these communities as well. For example, improving access to transformational technologies, enhancing safety

and security issues related to transportation technology services, and implementing anti-discrimination policies and training for service providers could all benefit these communities.

- **People Experiencing Homelessness.** Many of the strategies developed for people with low incomes, such as providing financial assistance and increasing access to alternative payment systems, could also apply to people experiencing homelessness, who often face financial insecurity and lack traditional banking options.
- **People Who are LGBTQIA+.** Many of the strategies developed could also be relevant for LGBTQIA+ individuals, such as creating inclusive transportation environments and providing training to transportation staff to ensure respectful and nondiscriminatory treatment. Building trust through enhanced safety and security measures and improving communication about services and options could also support LGBTQIA+ individuals.
- **People of Immigrant Communities.** In addition to several strategies that aim to enhance awareness, availability, and safety, the strategies developed for people who speak little or no English may also apply to immigrant populations. For instance, providing translation services related to transportation technology services and developing multilingual transportation resources could help support immigrant communities.
- **People Who Are Undocumented Immigrants.** Strategies aimed to bridge communication gaps and address language barriers, or those that aim to aid individuals without access to banking and create alternative payment solutions, are among the approaches that would improve access to essential services for people who do not have legal documentation when they crossed into the United States.
- **Women.** Strategies that specifically address safety and security concerns would be especially valuable in increasing the usage of transformational technology services among women, who are disproportionately affected by these issues.
- **People Traveling with Children.** Many of the strategies developed for individuals with disabilities, such as improving accessibility and providing accommodations, can apply to families traveling with children. It is important to recognize that families traveling with children have unique needs and considerations. Offering discounted or family-friendly pricing options for transportation services, providing information on affordable transportation options for families, and including designs that accommodate parents traveling with children, such as child seats or additional standing space, can greatly enhance the travel experience for families.

Playbook Overview

Playbook Vision

A playbook defines strategies and actions needed to achieve a goal. The "plays" in the playbook describe the situation, goals, key stakeholders, and actions needed to be successful. The characteristics of the plays incorporate processes, policies, and technologies that will impact successful outcomes.

This playbook offers potential strategies and actionable steps to address barriers to accessing transformative technologies to promote equity and support underserved populations. It aims to facilitate the inclusive deployment of transformative technologies to ensure broad access and benefit.

Playbook Audience

This playbook was developed for transit agencies, transportation planning organizations, mobility providers, state departments of transportation (DOTs), and other organizations that want to provide safe, fair, and accessible (public) transportation tailored to the needs of underserved populations.

Playbook Scope

This playbook covers a collection of strategies—aimed to help users develop an action plan based on their needs—that address three dimensions:

- **Goal.** The primary goal that organizations seek to achieve in a particular underserved community.
- **Service.** The target transformational technology to achieve the identified goal in the underserved community.
- **Population.** The target underserved community for which solutions are desired to increase use of and access to the technology identified.

Goal

There are many possible approaches to expanding access to transformational technologies. It is essential to first define the goal that is the focus of the effort to solve the challenges being faced by the target audience. Multiple goals may be achieved as this effort unfolds, and the potential for leveraging this commitment should be explored for an optimum solution.

Table 2 provides the goals that are considered within this playbook, together with icons that serve as indexes, allowing readers to quickly navigate and establish a direct connection with each goal.

Table 2. Goals considered in the playbook.

Index Icon	Goal	Description
	Availability	Enhance the availability of the technology, infrastructure, and assistive services needed to operate the service.
	Access to Technology	Enhance access to technology and remove barriers for people who lack the skills or abilities to use new technologies.
	Awareness	Raise awareness of the service and its features, such as safety features.
	Accessibility	Build for universal inclusion and remove barriers that prevent interaction with or use of the service, including for people with disabilities or other special needs.
	Safety and Security	Improve safety and security measures to mitigate concerns.
	Affordability	Boost affordability of the service.

Service and Population

The service dimension of this playbook focuses on the targeted transformational technology to achieve a specific identified goal in the target underserved community, while the target population dimension focuses on the specific underserved community for which a solution is needed to provide or enhance use of or access to an identified technology (as seen in Table 3).

This playbook was specifically developed with the aforementioned population groups in mind, but it is important to recognize that the services and strategies outlined within can be expanded to accommodate other underserved communities as well. The information, tools, and strategies presented in this playbook are transferable and should be considered when addressing the needs of new services or population groups.

The flexibility and adaptability of these approaches allow for customization and tailoring to various contexts, ensuring that the playbook remains a valuable resource for a wide range of stakeholders. By applying the principles and lessons learned from this playbook, decision-makers and practitioners can effectively address the unique challenges faced by underserved populations, regardless of the specific service or demographic focus.

Table 3. Target services and populations considered in the playbook.

Target Services	App-based carpooling services Bikesharing services Carsharing services E-scooter sharing services Ridehailing services Fully automated vehicle services
Target Populations	People aged 65 years or older People who speak little or no English People with disabilities People with low incomes People residing in rural areas or on tribal reservations

CHAPTER 2

How to Use This Playbook

Organizations planning to deploy transformational technologies need to ensure that they provide equitable service that is inclusive of underserved populations. This playbook helps identify the barriers that people in these communities face in accessing and using these mobility services.

This playbook describes scenarios that address specific barriers to accessing transformational technologies by recommending promising strategies to mitigate the obstacles to use. Each scenario is a formal play that includes a description of the barrier, the goal to be achieved, the target transformational technologies, the barriers to access, and the strategies to reduce gaps or mitigate barriers to the specific transformational technologies, including those that have been successfully applied by other organizations.

The Anatomy of a Play: What to Expect?

Chapter 3 provides the plays, which are organized into the following sections:

- **Summary Table.** Outlines the **goals**, **services**, and **populations** addressed.
- **Overview.** Describes the scenario and provides an overview of the topic.
- **Major Barriers.** Discusses major barriers faced by travelers. As applicable, this section cites results of the online survey that solicited information on barriers from the perspective of members of underserved communities as well as other concerns and barriers that might interact with the primary challenge described in the given scenario, as reported in the project's online survey, interviews, and focus groups.
- **Potential Strategies.** Presents tactics or policies that overcome the challenges described in the given scenario.

The strategies developed within the plays may overlap for various reasons, such as shared goals or interconnected focus areas like accessibility and safety. While these plays are designed to be independent and standalone, users are encouraged to explore the various plays, draw connections between them, and leverage collective knowledge and insights to inform their decision-making process. **By approaching the playbook as a cohesive resource, users can extract maximum value and uncover synergies that enhance the overall effectiveness of their efforts to address transportation challenges and serve underserved communities.**

The transformational technology plays, which are designated with a "TT" prefix, cover 10 scenarios. Table 4 provides a list of each play indexed by the goal, target service, and target underserved population.

- The first column of the play list table contains a link to the referenced play, allowing users to quickly navigate to the desired play. It also indicates the location of the play within the document, corresponding to a specific page number.

Table 4. Play list for transformational technology plays.

Prefix and Location	Title	Goal	Service	Population
Play TT-1 Starts on Page 16	Build Trust through Enhanced Security and Communication	Accessibility Safety and Security	App-based carpooling services Ridehailing services Fully automated vehicle services	People aged 65 years or older People who speak little or no English People with disabilities
Play TT-2 Starts on Page 19	Create Discount and Ease-of-Payment Programs	Affordability	Carsharing services Ridehailing services Fully automated vehicle services	People with low incomes People residing in rural areas or on tribal reservations
Play TT-3 Starts on Page 22	Expand Adaptive and Motor-Assisted Micromobility Fleets	Awareness Accessibility	Bikesharing services E-scooter sharing services	People aged 65 years or older People with disabilities
Play TT-4 Starts on Page 25	Boost Knowledge and Awareness of New Mobility Services	Awareness	App-based carpooling services Bikesharing services Carsharing services E-scooter sharing services Ridehailing services Fully automated vehicle services	People aged 65 years or older People who speak little or no English People with disabilities People with low incomes
Play TT-5 Starts on Page 28	Create Safe Infrastructure for Micromobility Services	Accessibility Safety and Security	Bikesharing services E-scooter sharing services	People aged 65 years or older People who speak little or no English People with disabilities People with low incomes People residing in rural areas or on tribal reservations
Play TT-6 Starts on Page 31	Facilitate Smartphone-, Data-, and Broadband-Free Ride Booking	Access to Technology	App-based carpooling services Bikesharing services Carsharing services E-scooter sharing services Ridehailing services Fully automated vehicle services	People aged 65 years or older People with low incomes People residing in rural areas or on tribal reservations
Play TT-7 Starts on Page 34	Expand New Mobility Services in Rural and Tribal Areas	Availability Access to Technology	App-based carpooling services Bikesharing services Carsharing services E-scooter sharing services Ridehailing services Fully automated vehicle services	People with low incomes People residing in rural areas or on tribal reservations
Play TT-8 Starts on Page 37	Implement Assistive Service Technologies in Vehicles	Awareness Accessibility Safety and Security	App-based carpooling services Ridehailing services Carsharing services Fully automated vehicle services	People aged 65 years or older People who speak little or no English People with disabilities
Play TT-9 Starts on Page 40	Improve Safety and Comfort for Shared Ride Services	Access to Technology Awareness Safety and Security	App-based carpooling services Ridehailing services Fully automated vehicle services	People aged 65 years or older People who speak little or no English People with disabilities People with low incomes People residing in rural areas or on tribal reservations
Play TT-10 Starts on Page 43	Promote Equitable Implementation of Shared AV Services	Availability	Fully automated vehicle services	People who speak little or no English People with low incomes People residing in rural areas or on tribal reservations

- With the play list table, anyone planning a project can first identify any of the three dimensions and then use the link under the play number to access the play.

Implementation Considerations

Following the plays, Chapter 4 provides a comprehensive overview of key questions and a checklist of implementation considerations related to the actions associated with each play that can help implementing organizations not only achieve long-term success but also manage expectations and maintain credibility.

The considerations and strategies clarify the intent of the service and the boundaries of its operations and should be reviewed at the **start** of any strategy implementation or deployment of transformational technologies.

The checklist includes considerations related to the following focus areas:

- Defining overall goals/objectives and opportunities/constraints.
- Communicating with the target population.
- Assessing funding approaches.
- Maintaining compliance.
- Evaluating vehicle autonomy.
- Exploring private-sector implications.
- Examining other specific factors.

Chapter 4 offers considerations about implementation duration and cost.

CHAPTER 3

Plays

This chapter presents 10 transformational technology plays, as indexed below. The following list is clickable, allowing users to navigate directly to the corresponding play. At the top of the page of each play in the playbook, icons representing the goals are provided as an index (as shown in Table 2). These icons enable users to quickly locate and navigate through the specific goals of each play.

- Play TT-1: Build Trust through Enhanced Security and Communication
- Play TT-2: Create Discount and Ease-of-Payment Programs
- Play TT-3: Expand Adaptive and Motor-Assisted Micromobility Fleets
- Play TT-4: Boost Knowledge and Awareness of New Mobility Services
- Play TT-5: Create Safe Infrastructure for Micromobility Services
- Play TT-6: Facilitate Smartphone-, Data-, and Broadband-Free Ride Booking
- Play TT-7: Expand New Mobility Services in Rural and Tribal Areas
- Play TT-8: Implement Assistive Service Technologies in Vehicles
- Play TT-9: Improve Safety and Comfort for Shared Ride Services
- Play TT-10: Promote Equitable Implementation of Shared AV Services

TT-1: Build Trust through Enhanced Security and Communication

GOAL	Accessibility Safety and Security
SERVICE	App-based carpooling services Ridehailing services Fully automated vehicle services
POPULATION	People aged 65 years or older People who speak little or no English People with disabilities

Overview

Ridehailing and app-based carpooling services have the potential to improve mobility outcomes for underserved populations. However, concerns regarding their safety and security can hinder individuals from fully embracing these services. Publicizing and enumerating the safe driving standards for ridehailing and app-based carpooling services is one viable solution to help foster trust in drivers by underserved populations, particularly older adults and people with disabilities. Additional measures such as providing increased education efforts, assistive drivers or attendants, safe rider checks, and additional app-related accessibility features would also help improve trust and increase service use if implemented in conjunction with the safety standards.

Major Barriers

Even though ridehailing and app-based carpooling companies require driver background checks, common worries for new riders include uncertainty about the experience and concerns about safety that stem from getting into a car with an unknown driver or sharing a ridehailing trip with strangers.

In a self-driving vehicle without a human driver, the concerns can be further amplified when there is no immediate human presence to mediate or address any conflicts or safety issues that may arise between passengers during the ride. The lack of a driver as a neutral authority figure may heighten feelings of vulnerability and discomfort.

According to this project's transformational technologies survey, concerns about unknown drivers and riding with strangers exist across all population groups but are most pronounced for older adults and people with disabilities. The following were among the top barriers:

- **Riding with unknown ridehailing drivers perceived as unsafe.**
- **Having safety concerns about carpooling with strangers.**
- **Needing to know a driver's background and driving record.**
- **Not feeling safe or comfortable when riding with other people without a driver.**

Underserved communities may have trouble using ridehailing or carpooling apps and/or communicating with the driver. People who speak little or no English may find it difficult to understand some drivers, while people with auditory disabilities may have challenges communicating with drivers who do not use sign language or other accessible communication methods. Similarly, people with ambulatory disabilities may have trouble finding accessible vehicles that can accommodate their needs. In addition, people with visual disabilities may face challenges in locating and safely accessing vehicles, particularly in crowded or unfamiliar areas. These

difficulties can lead to additional distrust in the service, amplifying the barriers and creating further challenges that limit adoption.

Potential Strategies

- **Specify driver match profile** for service providers to give riders the option to be matched only with a driver that meets specific criteria (passed background checks or maintained good driving records); this may include publicizing the company process for vetting drivers.
  - If used, this solution must be offered at no additional cost for rides with a safe-certified driver to avoid creating a higher-quality but unaffordable tier of service.
  - For app users, a safe-certified driver could be recognized by an icon next to the driver's profile information. This would not only incentivize drivers to work toward the necessary qualifications to join the safe driver list but also provide safety verification for riders. User ratings of driver safety could enhance the safety measures of the platform.
- **Employ safe rider checks** to ensure the safety and comfort of both the rider and the driver and address concerns related to sharing a ride with another unknown passenger.
  - A safe rider check could include measures such as verifying the rider's identity and screening riders for a history of bad or dangerous behavior in past rides that could compromise the safety of the ride and pose a risk to the driver or other passengers.
- **Enable audio/video monitoring or Share My Trip** to provide real-time trip status to a trusted contact (e.g., friend, family member, or caregiver).
- **Provide driver training or certification** to help drivers address different abilities and language barriers.
  - Provide training to drivers on communicating and assisting persons with different types of disabilities. Training programs such as the Passenger Assistance, Safety, and Sensitivity (PASS) driver certification program (Community Transportation Association of America n.d.) could be considered to provide help, assistance, and direction to riders if they request additional assistance.
  - Riders could similarly indicate through their user profile that they need an assistive driver for their ride and then get matched to an available driver with the assistive certification. Riders without a smartphone could call a third-party concierge service such as GoGo Grandparent or the Lime Access Program to communicate their needs to a representative and book an accessible ride.
  - Allow riders to request drivers equipped with knowledge and skills to respond to medical emergencies (e.g., EMT trained) and provide higher care and support to those in need, including older adults and people with disabilities, during their ride. Since this service would pose an additional training cost for third-party companies without a high ROI (due to the lack of need for riders without challenges from disabilities), this solution might benefit from partnership support to help with funding/incentivizing assistive training. To ensure the reduction of this barrier does not create a new barrier, an assistive driver should not pose an additional cost for the trip to the rider.
  - Provide basic, multilingual communication that is regionally and culturally appropriate and/or provide training to drivers on communication techniques when encountering riders who speak little or no English, regardless of a rider's spoken language. In addition, drivers could have access to smartphone language translation apps for driver and passenger communication.

In March 2021, Uber and Lyft launched the Industry Sharing Safety Program, which exchanges information between companies about drivers banned because of a sexual or physical assault charge to prevent these drivers from operating for other companies (West 2021).

- **Implement security features** to enable a secure and direct two-way communication channel between riders and a dedicated support team or emergency services. This strategy would allow riders to quickly report concerns, provide additional information, or receive guidance in emergencies. Examples include the following:
  - Real-time GPS tracking. Integrate real-time GPS tracking within the app to allow riders to share their trip details and location with trusted contacts or emergency contacts. This feature could provide an added layer of security by ensuring that someone knows the rider's whereabouts during the trip.
  - Panic button. Include a panic button in the app and the vehicle that riders could press in case of emergencies or when they feel threatened. This feature could immediately alert the service provider or emergency services and provide them with the rider's location for quick response and assistance.
  - Caregiver monitoring. Allow in-app, online, or audio monitoring by a caregiver during the ride, which could be especially important for riders who might have difficulty using in-app buttons/support mechanisms.
- **Implement robust passenger protocols for shared AVs** to ensure clear communication regarding safety guidelines, zero-tolerance policies for misconduct, and effective reporting mechanisms. Proactively address passenger-to-passenger safety concerns in self-driving ridehailing services to foster an environment of trust and reassurance.

TT-2: Create Discount and Ease-of-Payment Programs

GOAL	Affordability
SERVICE	Carsharing services Ridehailing services Fully automated vehicle services
POPULATION	People with low incomes People residing in rural areas or on tribal reservations

Overview

Ridehailing and carsharing services, along with future AV services, play a crucial role in facilitating access to employment opportunities, medical facilities, and other essential service locations. Keeping ride prices affordable will increase travel opportunities for underserved populations, for whom certain travel modes can be cost-prohibitive. To lower the cost and enhance the affordability of technology-driven mobility services, service providers could implement discount programs, subsidies, incentives, and other cost-reduction schemes. Service providers could also tap into local resources to reduce costs while expanding service coverage in areas with limited service, such as rural or tribal areas.

Major Barriers

According to the U.S. Census Bureau (2022), the official poverty rate in 2021 stood at 11.6%, with approximately 37.9 million people living below the poverty line. The high cost of transportation further exacerbates the financial challenges faced by those living in poverty. The Consumer Expenditure Survey (U.S. DOT, Bureau of Transportation Statistics, 2021) reveals that on average, households spent $10,961 on transportation in 2021.

The ability to afford a ride is a major concern, especially for people with low incomes. It is a crucial factor affecting the viability of existing ridehailing and carsharing services. This is also the case for future AV services; shared AV pilot deployers have faced challenges in determining how to set affordable trip pricing for underserved communities.

According to this project's transformational technologies survey, concerns over price exist across all population groups but are most pronounced for people with low incomes. The following were among the top barriers to affording new or future mobility services:

- **Carsharing hourly cost is too high.**
- **Ridehailing trip cost is too high.**
- **Self-driving vehicle services are too expensive.**

The variability of price is also a cause for concern for low-income populations, especially for those on a fixed income. The fear of uncertain prices, accidental charges, and billing issues further compounds the concerns faced by these individuals. Rural and tribal populations face additional affordability issues related to services being more limited and the need to travel longer distances, leading to higher per-trip costs. People who are unbanked or underbanked face additional barriers in using some existing forms of ridehailing and carsharing services due to payment restrictions exclusively to debit or credit cards. A significant portion of people with low incomes face challenges in accessing basic banking services and financial tools, with 43.7% of such households lacking access to credit cards (FDIC 2021). People who are undocumented immigrants may also hesitate to use a mobility app or connect to a bank for payment.

Potential Strategies

- **Implement free or discount programs** for mobility services for riders under a certain income threshold (e.g., below the poverty line) to improve access to these services for low-income populations. Funding from local, regional, or statewide sources could be considered, but funding is often a challenge, so this strategy may not be feasible in some communities.
  - State or regional policymakers could consider requiring subsidies or discount programs in rural and tribal areas as well as low-income neighborhoods for operators looking to obtain an operating permit.
- **Offer free or subsidized membership** and/or payments over time. For those who cannot afford the upfront membership costs of such services, discounted or subsidized memberships provided through nonprofit partnerships could ease the economic burden.
  - Allow options for low-income customers to pay for membership levels in smaller time increments (such as weekly or monthly) as well as single trips to help overcome the barrier of larger upfront costs.
- **Implement fare capping** for daily or monthly rides where service is free once a threshold is reached.
- **Develop alternative methods** to pay for services, without the need for a smartphone or credit card (accepted alternative forms of payment could include social security prepaid debit cards, cash, mail-in-payment, or prepaid balances).
  - Deploy information and payment kiosks at mobility hubs, key travel areas, public assistance offices, food banks, and underserved areas that allow for easier cash payment beyond purchasing debit cards at convenience stores.
  - Work with third-party retailers like convenience stores so that riders can pay for tickets or tokens (e.g., barcodes) using cash.
- **Implement account-based systems** that allow users to transfer transit subsidies to other on-demand services. This approach would enable individuals to use existing fare structures and discount programs, reducing the cost of new mobility services that are planned to be added to the network, such as shared AVs.
- **Expand service in lower-density areas**, such as rural/tribal areas, by recruiting drivers from senior centers and colleges to build rider pools (i.e., a group of riders willing to carpool) and driver pools to produce sustainable mobility markets and reduce costs.
- **Foster partnerships** to improve affordability and ease of access to payment. Examples include the following:
  - Collaborate with financial institutions to explore ways to integrate banking services, prepaid cards, or virtual wallets into the payment ecosystem, making it easier for people without traditional banking access to participate in the ridesharing economy.
  - Leverage the expertise of digital payment platforms and payment service providers to develop innovative payment solutions tailored to the needs of low-income populations. This might include features such as flexible payment plans, discounted fares, or alternative payment methods.
  - Encourage shared AV providers to seek both public and private grant funding opportunities to offer more affordable and accessible trips for underserved populations. Regional and state DOTs could offer two-phase grant programs, with initial financing for setup and a second phase after proof of successful implementation.
- **Consider neighborhood or community-based operations** through community groups that enable affordable travel options.
  - Identify an affordable pricing scheme and suitable alternative payment systems for the local area with community groups.
  - Collaborate with community groups to source alternative financing for the program.

PayNearMe/Lime Access allows users to purchase a payment code that unlocks a shared scooter with cash at convenience stores (PayNearMe 2018).

Los Angeles Department of Transportation (LADOT) is experimenting with low-cost neighborhood van shuttle services for inter-neighborhood trips, which could be expanded in the future to feature shared AVs (LADOT n.d.).

- **Launch public awareness campaigns** to inform people with low incomes about the reduced prices, free services, or new payment options available, highlighting their benefits, ease of use, and affordability. This could be done using flyers, newsletters, radio broadcasts, and word of mouth, with efforts targeted at lower-income communities. Local champions who can help educate their communities about available services and payment options are also key in gaining support.
- **Implement pilot programs** to measure the impact of any reduced or free trip program, with performance metrics focused on the increased usage of these services by low-income populations.
  - Performance metrics should go beyond traditional ridership calculations and assess levels of increased access to destinations and affordability of service resulting from program design. This would require ridehailing, carsharing, and AV service companies to engage customers in questionnaires or demographic surveys.
  - If the pilot study were conducted in a low-income neighborhood and was successful, planners and advocates could work together to develop long-term plans to sustain, scale up, or expand the program design to more areas.

TT-3: Expand Adaptive and Motor-Assisted Micromobility Fleets

GOAL	Awareness Accessibility
SERVICE	Bikesharing services E-scooter sharing services
POPULATION	People aged 65 years or older People with disabilities

Overview

New micromobility options such as docked and dockless bikesharing and e-scooter services have increased short-trip mobility in cities where the technology has been implemented. Motor-assisted micromobility vehicles, such as e-bikes and e-scooters, can provide increased mobility options for those who may have difficulty walking long distances or using traditional bicycles. On the other hand, physical ability barriers and cognitive skill requirements for micromobility use can pose significant challenges to older adults and people with disabilities. Improving the accessibility of these micromobility vehicles depends on both investment in and deployment of adaptive vehicles, along with training and awareness efforts. Adaptive vehicles and training instructions can be tailored for people with a multitude of abilities, comfort levels, and trust levels in micromobility services.

Major Barriers

The majority of vehicles offered by micromobility services are inaccessible to older adults and people with disabilities. This barrier is intersectional with a significant overlap between the two, with disabilities particularly prevalent among older adults. According to the U.S. Census Bureau (2021), people with disabilities account for 13% of the U.S. population, or approximately 42.5 million, and older adults account for 17% of the population, or approximately 55.9 million people. Among older adults, 20.5% have an ambulatory disability, 13.3% have a hearing disability, 7.8% have a cognitive disability, and 6% have a vision disability (U.S. Census Bureau 2021).

According to this project's transformational technologies survey, more than one-third of older adults and people with disabilities, and one-quarter of rural residents and people with low incomes

- **Cannot use bicycles due to a disability or age.**
- **Cannot use e-scooters due to a disability or age.**

Beyond the ability to use the vehicle, additional barriers are present in accessing training materials and performing booking and account administration. Materials without accessibility and language adaptations may be inaccessible to people with auditory, visual, or cognitive disabilities, as well as to people who speak little or no English. Furthermore, micromobility devices may not be designed to accommodate the needs of families or caretakers, which can make it impractical or unsafe for those traveling with children or individuals with specific needs to use these services.

Potential Strategies

- **Increase the size and availability** of adaptive and motor-assisted micromobility fleets.
  - Work with people with disabilities and relevant advocacy or social service organizations to identify the needs and gaps for adaptive bikes, e-bikes, and e-scooters.

  - Work with municipalities and service providers to appropriately scale the number of accessible fleet vehicles and rebalance fleet supply resulting from operational demands.
  - Establish partnerships (such as public-private partnerships) to promote micromobility as a viable travel alternative for all and promote equitable distribution of resources and funding.
  - Take into account different needs when deploying adaptive fleets. For example, handcycles work well for some people with ambulatory disabilities. Tandem bikes could be used as a solution for increasing access to bikeshare for those who cannot use handcycles.

- University of Maryland-College Park's pilot bikesharing program, mBike, has included tricycles and side-by-side two-person bikes in its vehicle fleet (Tyson 2016).
- Oakland's bikeshare program includes adaptive vehicle options such as handcycles, tricycles, tandem tricycles, and other devices within the bikeshare fleet (Baldassari 2019).
- New York City's Citi Bikes e-bike program has expanded to include the integration of several thousand pedal-assist bikes (Citi Bike n.d.).

- **Increase amenities for families and caretakers** because the lack of amenities that support safe and convenient travel for families and caretakers could deter them from choosing micromobility options. Develop or promote micromobility services that are specifically designed to accommodate families and caretakers.
  - Feature larger vehicles or attachments to accommodate children, such as cargo bikes with seating for multiple passengers or e-scooters with add-on seats for children.
  - Make attachable children's seats available at bike stations for riders to attach to the back of their bikes. Sanitation procedures for pre- and post-use should be incorporated.
- **Deploy more accessible mobility apps** to improve access to on-demand bike and e-scooter sharing services. App developers should use the U.S. Department of Justice webpage's accessibility checklist, which evaluates the extent to which webpages and apps are accessible to most people with disabilities.
- **Ensure accessible infrastructure** in the immediate area surrounding stations to allow riders to easily navigate before and after micromobility use. Large, level sidewalks and ramps should be considered as minimum requirements for station areas.
  - Enact complementary public policy to enforce penalties for leaving bikes/e-scooters in unauthorized locations, thus reducing hazardous sidewalk conditions and encouraging more favorable attitudes toward micromobility services.
  - In rural settings, identify use cases and main street zones for micromobility. Complementing these use cases with safe infrastructure and wayfinding signage could provide a useful local travel option for short trips.
  - Support the development of integrated infrastructure (such as through enhancing the integration between adaptive micromobility services and public transportation) to ensure seamless travel options and cater to the specific needs of individuals with disabilities, older adults, and families.
- **Organize community events, workshops, and group rides** to foster a sense of belonging and inclusivity and expand hands-on experience using adaptive bikes, e-bikes, and e-scooter fleets.
  - Encourage participants from diverse backgrounds to share their experiences, build connections, and challenge stereotypes. There is a diversity of needs, especially among people with disabilities, and listening to people from different communities and population groups could provide unique insight that translates into a more accessible experience for everyone.
  - Tailor messaging and outreach efforts to address specific cultural concerns or perceptions related to the use of micromobility services among people with disabilities and older adults. Engage community leaders,

Tulsa's bikeshare system, This Machine, used grant funds to hire a community coordinator, who served as a Latino-culture-competent Spanish translator and event lead (Better Bike Share 2021).

influencers, and organizations to promote positive narratives around micromobility use within their respective cultural contexts. Also, ensure that language barriers do not hinder access to information and guidelines.

– Engage advocacy and social service groups to identify travel needs and demonstrate that micromobility services can be use as viable transportation options. Such groups may also be available to hire as community coordinators or ambassadors.

TT-4: Boost Knowledge and Awareness of New Mobility Services

GOAL	Awareness
SERVICE	App-based carpooling services Bikesharing services Carsharing services E-scooter sharing services Ridehailing services Fully automated vehicle services
POPULATION	People aged 65 years or older People who speak little or no English People with disabilities People with low incomes

Overview

New mobility services can dramatically increase mobility for populations without a car or who rely on one mode of transportation. Promoting new mobility services for all underserved populations is crucial to ensure equitable access and transportation options for everyone, regardless of their socioeconomic status, geographic location, or physical abilities. However, the lack of knowledge, awareness, and acceptance of new mobility options leads to misconceptions about vehicle capabilities, ease of use, and safety and poses significant challenges to the use of these services. To improve service use among underserved populations, initiatives should focus on creating inclusive knowledge sharing and fostering awareness and acceptance through targeted outreach, accessible information, and community engagement and training.

Major Barriers

New mobility services are usually based on novel technologies, with which many people are unfamiliar. A lack of knowledge and awareness creates safety perception issues and feelings of being unable to use technology, resulting in lower service use. Information and experiences related to new mobility options often rely on internet connectivity and may not be readily available in non-English languages or formats that are accessible for people with disabilities (such as related to user interfaces and information provision). For micromobility services, learning to use the vehicles may also be a barrier.

According to this project's transformational technologies survey, lack of information or knowledge is a critical cause for concern for all five target audiences, specifically in terms of

- **Not enough information about carsharing.**
- **Not knowing how to ride an e-scooter.**

In addition, a greater familiarity with shared AVs was associated with more positive attitudes toward the technology, and respondents who were less familiar with shared AVs were the most likely to have negative perceptions of the technology.

Lack of information surrounding pricing, availability, and practical use aspects of new mobility services are among the barriers in areas where service is available. However, people with low incomes and people living in rural areas face additional barriers to using new mobility services, particularly carsharing programs. These additional barriers include large upfront costs for an annual membership; high individual trip costs, especially long-distance rides; and a lack of

vehicles or services in the local area. Furthermore, the absence of universal design principles impedes the accessibility and usability of these services.

Potential Strategies

- **Increase service awareness and provide information** through campaigns in culturally and regionally appropriate languages about how to use new mobility services to educate potential riders and resolve misperceptions. Service awareness could be created through flyers, newsletters, and television and radio broadcasts.
  - Work with community leaders and organizations to improve customer awareness through education efforts and spread information through word of mouth.
  - Focus on communication and education efforts in areas that the populations of concern frequent (e.g., grocery stores, churches, healthcare centers, bars and restaurants, schools and universities, shopping centers, large employers).
  - Emphasize in-person engagement through the mobilization of street teams to improve access to information about new mobility services. Launch public campaigns and organize events to provide live demonstrations and on-site information sharing.
  - Establish accessible information centers in community spaces, such as libraries, community centers, or disability service centers, where individuals can access user-friendly information about new mobility services.
  - Build service awareness in rural and tribal areas as well as other areas where services are not yet available to create demand for these services, encourage community participation, and promote ridership from the start of service.
- **Provide travel training or mentoring programs** that aim to educate individuals on how to use new mobility services effectively and safely. By providing hands-on guidance, informational resources, and support from trained mentors, participants can gain the necessary knowledge and skills to confidently navigate and use these services.
  - Establish partnerships with service providers to foster experiences and learning, such as learn-to-ride programs that offer training and mentoring opportunities. Hands-on, interactive, and on-site training can be effective, and call-in support lines and buddy programs can help to better understand options.
  - Engage and involve community members and advocacy organizations at the local, regional, and national levels to develop workshops, training programs, and peer-to-peer initiatives to ensure extending access to underserved communities.
- **Actively seek feedback and develop information channels** to track common questions and misperceptions and address concerns as they arise.
  - Adapt and improve training materials proactively. Establish where reputable information can be found both from ambassadors in community groups and online platforms. Responses to common concerns should be detailed and match in-person communication with community members.
  - Engage in user testing and involve individuals with disabilities, older adults, and other target populations in pilot projects to ensure that services are inclusive, user-friendly, and meet their specific needs.
- **Develop interactive guidance and support** for populations less familiar and comfortable with new mobility services.
  - Produce interactive videos, online tutorials, or mobile applications that offer step-by-step guidance on how to use and benefit from these services.

- Detroit's MoGo program trains ambassadors to help engage peers in their communities about using micromobility services (MoGo n.d.).
- AARP's Ride@50+ training program helps older adults find and book transportation and offers online training on accessing these services (AARP n.d.).
- The Lyft/Best Buddies program, which serves people with intellectual and developmental disabilities, provides participants with transportation training (Best Buddies n.d.).

SilverRide's concierge service provides fully assisted rides tailored to the needs of the rider (SilverRide n.d.).

  - Develop assistive technology to ease the ride experience and provide support for using the new mobility services.
- **Tailor outreach efforts** to consider the varying levels of access to information within different communities to maximize relevance and effectiveness.
  - Recognize the differences among underserved communities in accessing information, such as cultural norms, values, and prevalent communication styles; different learning styles (e.g., visual, auditory, kinesthetic); and disability types (e.g., visual, hearing, cognitive). Tailor information to effectively reach the target community.
  - Ensure that digital platforms, websites, and online resources related to new services are accessible to people with disabilities and those who speak little or no English.
  - Collaborate with community organizations, advocacy groups, and social workers on the development and dissemination of information, materials, and resources that are accessible, inclusive, and multilingual.
- **Acknowledge potential cultural stigma against new mobility services** because culturally integrated, trusted community partners could be essential in bridging cultural gaps, reaching out effectively to targeted audiences, and fostering interest in stigmatized services. For example, for some non-White travelers, there might be a perception that using a bicycle or e-scooter could make a person more susceptible to unlawful stops from law enforcement or increase the risk of potential danger (compared to traveling in an automobile).

TT-5: Create Safe Infrastructure for Micromobility Services

GOAL	Accessibility Safety and Security
SERVICE	Bikesharing services E-scooter sharing services
POPULATION	People aged 65 years or older People who speak little or no English People with disabilities People with low incomes People residing in rural areas or on tribal reservations

Overview

Micromobility services offer affordable mobility options and enhanced short-distance travel for underserved populations, particularly those who do not drive or have limited access to private transportation. On the other hand, the lack of safe traffic separation infrastructure, like protected bike lanes, poses real dangers to micromobility users, creating a barrier for current and potential riders. If a potential rider's risk assessment determines the conditions are too unsafe for their comfort, it will likely prevent their use of the services. Creating safe infrastructure, ideally fully separating motorized traffic from micromobility riders, can reduce fear and increase willingness to adopt micromobility.

Major Barriers

Micromobility services have not reached the cultural acceptance threshold to be widely considered usable. This can be linked to key concerns regarding safety, lack of service for children and adolescents, and lack of adaptive vehicles. People with disabilities using nonadaptive vehicles may feel an increased safety risk, while people without proper safety equipment (e.g., helmets) may decline to partake in micromobility.

In this project's transformational technologies survey, the following concerns were prominent, especially among rural community members, older adults, and people with disabilities:

- **There are no bike lanes in the area.**
- **Riding a bike in the area is not safe.**
- **Riding an e-scooter in the area is not safe.**

Respondents cited lower concern about riding without a helmet, even though helmet-wearing is important to reduce the risk of serious injury in case of a fall. However, the impact of safe infrastructure is substantial. The implementation of safe infrastructure, such as protected bike lanes, has been shown to significantly reduce injury rates for all road users (Urban Institute 2022). Despite the safety enhancements, people may still experience a sense of insecurity when using these services. For example, people with disabilities face multiple layers of inaccessibility with micromobility. Without adaptive vehicles and accessible road infrastructure, a potential rider could be prevented from navigating on a bike or e-scooter. People traveling with children are unaccounted for in bikeshare and e-scooter share designs, while older children are not able to use micromobility services until the age of 18. Furthermore, biking carries a stigma among certain communities, which may lead to avoidance of bikesharing services.

Potential Strategies

- **Implement new infrastructure and bolster older infrastructure** by performing feasibility studies to prioritize the identification of suitable locations to implement new infrastructure or improve existing infrastructure.
  - Improve infrastructure by adding high-comfort infrastructure elements for bicycles and e-scooters, such as traffic signals that support phasing for these users.
  - Increase driver awareness of micromobility and improve rider safety as well as the perception of safety by implementing new infrastructure (including signage for motor vehicle drivers designed to increase their awareness).
  - Work with people with disabilities in the community as well as advocacy and social service organizations to collect their input on specific micromobility vehicles and infrastructure needs to make them safe and accessible.
  - Incorporate universal design principles into the planning and implementation of projects for micromobility services. Consider the diverse range of users and integrate features to enhance accessibility and navigation for individuals with different abilities.
- **Explore feasible and flexible infrastructure solutions**, for example
  - Assess the allocation of road space and explore opportunities to repurpose or reallocate lanes to accommodate micromobility services (e.g., repurposing underused spaces).
  - Explore adaptable infrastructure options that could accommodate varying levels of demand and usage patterns. This might include innovative solutions such as pop-up bike lanes or shared street concepts that could be adjusted based on changing needs. This strategy might be particularly useful when building new infrastructure is too costly or the current streetscape does not allow room for additional lanes.
  - Work closely with local planners to ensure that micromobility infrastructure is considered alongside other modes of transportation, aligns with long-term urban development goals, and becomes part of the regional transportation plans.
- **Continuously monitor and evaluate the performance of implemented infrastructure improvements**, considering factors such as safety, usage rates, user satisfaction, and impact on overall transportation efficiency.
  - An iterative feedback process helps refine and optimize the infrastructure to meet the evolving needs of micromobility services and their users. Use these data to inform future decision-making and prioritize areas for improvement or expansion.
- **Identify and pursue funding opportunities** through grants, partnerships, and government programs dedicated to transportation infrastructure development. Advocate for dedicated funding streams to ensure sustained support for ongoing maintenance and expansion efforts.
  - Involve local communities, neighborhood associations, and micromobility users in the planning and design process. Solicit their input and feedback to ensure that the new infrastructure meets their specific needs, addresses concerns, and reflects the character of the community. Implement pilot projects to test their effectiveness and feasibility.
- **Implement safety equipment programs** to increase user comfort, safety, and perception of safety for those populations without access to safety equipment.
  - Provide discounted or free safety equipment to encourage its use (such as helmets, reflective gear, lights, and other protective accessories).
  - Partner with service providers to work toward subsidizing the cost for users.
  - Integrate safety equipment provisions into micromobility rental systems and install temporary safety equipment checkout kiosks or equipment that attaches on and off the micromobility vehicle (requires cleaning/sanitation of equipment/services).

A micromobility fee funding program in Santa Monica used the public right-of-way fees paid by e-scooter operators to update 19 miles of existing bike lanes in 2019 (National Association of City Transportation Officials 2019).

  - Develop safety education programs that focus on educating users about the importance of wearing safety equipment and following traffic rules. A specific example would be to create campaigns about the personal safety benefits of helmet-wearing in case of falls and crashes not involving motorized vehicles. Ensure that awareness campaigns are culturally sensitive and avoid perpetuating stigmas.
  - Collaborate with local businesses or community organizations to organize safety equipment giveaways, events, or workshops to engage the community.
  - Regularly evaluate the effectiveness of safety equipment programs through data collection, user surveys, and incident reporting.
- **Address varying safety concerns of new micromobility services** given that micromobility services have different aspects and potential risks. Some may perceive e-scooters as less safe than bicycles. Implementing and publicizing common expectations for e-scooter riders, pedestrians, and drivers surrounding right-of-way, road rules, and minimum distance between vehicles and people would help create order and increased comfort while interacting with e-scooters. Set safe maximum speeds for e-scooters to reduce the risk of serious crashes and injury.

TT-6: Facilitate Smartphone-, Data-, and Broadband-Free Ride Booking

GOAL	Access to Technology
SERVICE	App-based carpooling services Bikesharing services Carsharing services E-scooter sharing services Ridehailing services Fully automated vehicle services
POPULATION	People aged 65 years or older People with low incomes People residing in rural areas or on tribal reservations

Overview

While providing essential mobility expansion, new mobility services largely depend on and assume that riders have a smartphone, cellular data access, and/or broadband capabilities. Similarly, future AV services, such as shared AVs, are often planned around such technologies for ride booking or fare collection. These assumptions create fundamental barriers for current or future riders, such as unbanked and underbanked individuals, who lack access to such tools to use the services. Potential riders without access to these technologies may be discouraged or deterred from engaging with new mobility options. Introducing modifications that allow users to book or pay for new mobility services with limited or no use of smartphones, cellular data, and/or broadband will make these services more accessible.

Major Barriers

The reliance of new mobility services on smartphones, cellular data, and broadband capabilities creates a digital divide and disproportionally affects those who may stand to benefit the most from transformational technologies. According to the Pew Research Center (2021), the share of Americans who own a smartphone is 85%, but a notable discrepancy exists in smartphone usage among adults aged 65 or older (61%), those with an income less than $30,000 (76%), and those living in rural areas (80%). If a potential rider does not have a smartphone, they will not be able to download the app.

Approximately 24% of households living below the poverty line do not have access to a smartphone (Pew Research Center 2021), showing a clear association between low-income households and a lack of smartphones. People with low incomes are also more likely to have irregular or slow access to data and broadband and may frequently change phone numbers. People in rural areas may also have low broadband and/or data coverage in their area. Both cases make loading and using an app-based service difficult. The issue can be further exacerbated for individuals who are not comfortable using technological devices.

In this project's transformational technologies survey, concerns were prominent in the following areas, especially among older adults and those living in rural areas:

- **Do not have a smartphone to access app-based carpooling services.**
- **Do not have a smartphone to access ridehailing services.**
- **Do not have a smartphone to access carsharing services.**

Additional barriers persist for individuals who have limited or no access to a bank account, including people who are undocumented immigrants who face additional hurdles when using

mobility apps or establishing connections with a bank account. In 2021, approximately 4.5% of U.S. households were classified as unbanked, indicating that no member of the household had a traditional bank account, and over 30% of unbanked households relied on prepaid cards (FDIC 2021).

Potential Strategies

- **Implement programs that aim to bridge the digital divide** by providing subsidized or low-cost smartphones, data plans, and broadband services to underserved communities. This could be achieved through public-private partnerships, government subsidies, or community-driven initiatives.
  - Implement pilot programs in select areas to test the effectiveness of modifications or new programs and gather feedback from users.
  - Provide digital literacy training programs to empower individuals in underserved communities with the necessary skills to effectively use smartphones, data plans, and broadband services.
- **Launch campaigns to raise awareness** about the availability of alternative booking and payment options and the steps needed to access and use them.
  - Create user-friendly guides, instructions, and tutorials that explain the steps involved in accessing and using the alternative booking and payment options.
  - Customize the campaign messaging to resonate with different target audiences and address their specific concerns and motivations regarding the adoption of alternative booking and payment options.
  - Partner with community influencers, local leaders, and organizations to amplify the campaign's reach and credibility.
- **Implement "lite" versions of mobility apps** that use less data and explore options to develop offline capabilities within mobility service applications.
  - Implement modified app functionality and supplementary programs that aid in the usage of new mobility infrastructure to help combat cellular data and/or broadband limitations.
  - Employ modified or offline modes to enable users to access previously downloaded maps, schedules, and booking options, ensuring continued service availability in areas with limited or no network coverage.
- **Enhance access** by providing free or affordable access to internet connectivity.
  - Invest in the expansion of public Wi-Fi networks, particularly in underserved areas and public transportation hubs.
    - Provide free internet access at key points of travel to broaden the availability of high-speed internet.
    - Set up community centers equipped with computers and internet access in underserved areas. These centers can serve as hubs for digital inclusion, offering training, assistance, and resources to help individuals overcome barriers and become digitally connected.
- **Implement concierge services** for payment, proof of payment, and on-demand hailing, thus improving access for those without the necessary technology, such as smartphones, cellular data, and/or broadband. Solutions include
  - Allow ridehailing requests and reservations to be made by a third party.
  - Provide SMS (text message) access-based systems to request a ride.
  - Create interactive voice response systems to book a ride or make a payment.

24 Hour Home Care (n.d.) created a program, RideWith24, that provides concierge services over the phone for ridehailing and accepts multiple forms of payment, including social security prepaid debit cards, cash, mail-in payment, or prepaid balances, thus eliminating the need for a smartphone or credit card.

- **Deploy mobility kiosks** for hailing vehicles at key hub locations and in town centers so people can request trips at both ends of their trip. Kiosks allow people to make trip requests by interacting with the reservation system without a phone.
- **Allow walk-ons on service vehicles**, such as ridehailing or microtransit vehicles at key stops or points; riders would then input their destination on a tablet onboard the vehicle or share their destination with the driver.
- **Provide paper membership applications** at community centers by offering physical forms for membership sign-ups to allow individuals to easily apply for membership and access mobility services without the requirement of online connectivity.
- **Integrate various payment options**, such as transit smartcards or prepaid cards, into shared-use services, making them available for purchase or reloading at locations such as convenience stores.
- **Provide trip information screens** in new mobility service vehicles to allow riders to receive up-to-date trip information, including pickup and drop-off locations, route guidance, and any necessary updates or changes.

Pittsburgh's bikeshare program, POGOH, offers smartphone-free registration through a customer support hotline, providing individuals with a membership card to access and rent bikes from any dock in the program (POGOH n.d.).

TT-7: Expand New Mobility Services in Rural and Tribal Areas

GOAL	Availability Access to Technology
SERVICE	App-based carpooling services Bikesharing services Carsharing services E-scooter sharing services Ridehailing services Fully automated vehicle services
POPULATION	People with low incomes People residing in rural areas or on tribal reservations

Overview

New mobility services can improve access to transportation and provide greater travel opportunities for rural and tribal communities to increase access to jobs, healthcare facilities, and other key services. New mobility hubs began and are predominantly located in wealthier, urban areas, rather than in low-income neighborhoods or rural areas. This perpetuates the concentration of economic resources in affluent areas while contributing to economic stagnation in rural regions. Rural areas present a challenge to urban mobility models due to low rider density, driver scarcity, and low technology access. Community-based programs and locally driven funding mechanisms can lower costs and increase the feasibility and future sustainability of new mobility options in rural and tribal areas. Service providers can also institute recruitment programs for drivers and/or support staff to expand services and bring down costs in areas with limited service availability, such as rural and tribal areas.

Major Barriers

According to the 2020 U.S. Census, approximately 20% of the U.S. population resides in rural areas (U.S. Census Bureau 2020). Additionally, based on the 2021 U.S. ACS data, American Indians and Alaska Natives, either alone or in combination with other races, make up 2.9% of the U.S. population (U.S. Census Bureau 2021).

No or limited service availability is the primary barrier to access to new mobility in rural and tribal areas. As of 2019, 17% of rural areas and 21% of tribal lands lacked fixed broadband, with the least deployment in Alaskan villages [Federal Communications Commission (FCC) 2021]. Moreover, in 2019, the broadband adoption rate was 73% in urban areas, 65% in rural areas, and as low as 41% in tribal areas (FCC 2021). Based on data from the Pew Research Center, Vogels (2021) noted that "rural adults remain less likely than suburban adults to have home broadband and less likely than urban adults to own a smartphone, tablet computer or traditional computer." In 2021, 20% of rural residents lacked a smartphone (Pew Research Center 2021), and in 2018, 25% of Native Americans and Alaskans did not own smartphones (Public Use Microdata Sample 2021). Furthermore, according to this project's gap analysis—based on data from FDIC (2018), Pew Research Center (2018), and Public Use Microdata Sample (2018)—rural populations are more likely to be older, have disabilities, and have low incomes. These compounding technology barriers must be addressed equally for successful program deployment.

According to this project's transformational technologies survey, the lack of available services is a significant issue for all underserved populations, particularly among rural communities. Nearly half of the participants indicated the following:

- **No carsharing vehicles/services in the area.**
- **No or limited ridehailing services in the area.**
- **No bikesharing services in the area.**
- **No e-scooter sharing services in the area.**

In rural and tribal areas, longer average trip distances and driver scarcity also pose significant challenges for mobility programs. In addition, the challenging nature of the road network, which may require the use of heavy-duty vehicles capable of navigating harsh conditions like unpaved roads, introduces further complexities regarding vehicle adjustments. As a result, new mobility options often become excessively expensive for users, creating barriers to affordable transportation in these settings.

Potential Strategies

- **Invest in rural and tribal area infrastructure** and services for new mobility modes and expand coverage of new mobility modes, combining elements of both systematic and agile processes to remain responsive and adaptable to the specific needs and dynamics of these communities.
  - Invest in the development of a conceptual framework that could proactively respond to the needs, including strategic planning, stakeholder engagement, infrastructure development, and expansion efforts.
  - Incorporate agile elements to allow flexibility in responding to community feedback, adjusting plans based on emerging challenges, and optimizing service delivery as the project progresses.
  - Improve digital infrastructure and public access to the internet through broadband program expansion and public Wi-Fi networks.
- **Incorporate vehicle adjustments and modifications** in new mobility service fleets that address the unique challenges of operating in these areas.
  - Improve ground clearance, equip with all-terrain tires, upgrade vehicle suspension systems, and incorporate weather-resistance features. Adding four-wheel drive vehicles into ridehailing fleets could help address the challenges of operating in rural and tribal communities with dirt roads or challenging weather.
  - Prioritize ADA-compliant vehicles to better serve aging rural areas.
- **Take advantage of funding opportunities** from federal, state, and local programs to alleviate the high costs of operations in rural or tribal areas to expand new mobility modes and services.
  - Set up service models that take trip requests from riders, consider their specific needs, and match them to available providers that help them complete the trip.
- **Foster partnerships and synergies** that bring together community organizations, local governments, and public-private partnerships to pool resources, expertise, and funding for developing new services or expanding existing services in rural and tribal areas.
  - Encourage state or regional policymakers to consider streamlining the permitting process and mandating that operators seeking operating permits in urban environments also provide services in rural and tribal areas.
- **Establish local volunteer driver programs** that provide coverage for people with low incomes and older adults in places with transportation gaps. With necessary investment and training, these programs can implement reservations, scheduling, and dispatch technologies to replicate many aspects of on-demand services rather than requiring advanced trip reservations.

JAUNT regional transportation service in Virginia provides fare-free transportation services, operating with financial assistance from community partnerships, federal and state transit grants, and local government funding support (JAUNT n.d.).

- **Involve the local community in the planning and implementation** of mobility services, ensuring that their unique needs and preferences are considered.
  - Organize community meetings and consultations to gather input from residents, local organizations, and tribal leaders.
  - Form community advisory committees and implement a feedback mechanism to understand mobility challenges and diverse needs in rural and tribal areas.
  - Develop small-scale pilot projects to test new mobility modes and their viability in rural and tribal areas.
  - Expand coverage gradually by prioritizing areas with higher transportation needs and limited existing options.
- **Adopt a community-based model** to
  - Allow residents to check out bikes from community centers (such as a public library), creating more localized opportunities for new mobility services [e.g., Thrive Allen County's (n.d.) program in Kansas]. This strategy may require additional funding and effort to keep track of and recover lost bikes and e-scooters.
  - Recruit drivers and riders in rural areas. Establishing vanpools and carpools can serve as effective means of transportation while using convenient park-and-ride lots as meeting spots can enhance access and convenience for participants.
- **Explore innovative funding mechanisms** and establish funding mechanisms that are specific to the local context to secure financial resources for sustaining and scaling up these services (such as grants, subsidies, public-private partnerships, or crowdfunding).
  - Apply operator fees in existing service areas to subsidize expansion into areas without current operations (such as rural or tribal areas).
  - Establish financing support from local transit agencies to develop new mobility options in serving lower-density areas as a solution to last-mile transit problems.
  - Explore the option of impact investment funds by collaborating with private firms or organizations that focus on supporting projects with a social and environmental benefit.

A partnership between four transit agencies in Oklahoma, PICK Transportation received an FTA Integrated Mobility Innovation grant to fund the microtransit service across 21 counties in the region (Shared-Use Mobility Center 2021).

TT-8: Implement Assistive Service Technologies in Vehicles

GOAL	Awareness Accessibility Safety and Security
SERVICE	App-based carpooling services Ridehailing services Carsharing services Fully automated vehicle services
POPULATION	People aged 65 years or older People who speak little or no English People with disabilities

Overview

As new mobility services evolve, it will become increasingly important to integrate assistive service technologies to overcome the barrier of accessibility and the usability of these services. Addressing concerns will require elements, including ADA-trained attendants; monitoring and concierge technologies; adapted, accessible vehicle designs, like wheelchair-accessible vehicles (WAVs); and in-app translation services. Operators for new mobility services should also ensure the maximized availability of accessible vehicles during peak travel periods. Early and frequent engagement opportunities during the deployment process can guide vehicle design and increase the transparency of the deployment process, which will be particularly crucial for future shared AV services. Integrating assistive technology will expand mobility opportunities for older adults, people with disabilities, and people with limited or no English, among others.

Major Barriers

The challenges related to accessibility and usability are among the factors that significantly hinder the integration of new mobility services into mainstream transportation systems. Ridehailing, app-based carpooling, and carsharing services, whether in their current conventional forms or as potential use cases of AVs, all encounter unique barriers. One such barrier is the technological requirements, which are not universally accessible. Immediate access is not provided by smartphone ownership and broadband access alone.

For people with visual disabilities, identifying ridehailing vehicles as they approach can be challenging without assistance. People with hearing disabilities may encounter difficulties in communicating with their drivers before or during a ride since communication is primarily verbal while the vehicle is in motion. Individuals who speak little or no English may face similar challenges in communicating with their drivers. Moreover, some people may experience panic when faced with drivers or passengers they cannot easily communicate with.

Driverless AVs are still under development and are eventually intended to be used without the assistance of a supplemental onboard operator. The possibility of future AVs being inaccessible for individuals with various disabilities also presents a significant barrier to their use, perpetuating the current lack of service, such as for people with disabilities, in ridehailing and carsharing programs.

In this project's transformational technologies survey, respondents identified varying concerns, such as

- **Difficulty understanding drivers in ridehailing services.**
- **Vehicles not being accessible for people with wheelchairs or motorized scooters.**
- **Self-driving vehicles not being accessible.**

The expenses involved in producing specialized modifications or dedicated accessible vehicles limit their availability and increase their rarity. Additionally, AVs deployed in on-demand services, such as ridehailing scenarios, will likely be as much if not more expensive than traditional services. This combination of high production costs and increased operational expenses hinders widespread adoption and accessibility, impacting individuals with disabilities and older adults. Moreover, without government subsidies or private discount programs, this service will remain out of reach for people with low incomes.

Potential Strategies

- **Identify the need and develop varying programs with assistive service technologies and adaptive infrastructure** since there are no one-size-fits-all modified solutions. These programs might include human assistance services as well as other supporting technologies that provide direction, information, and support on how to use and access vehicle and trip services to ensure a safe and easy-to-use trip. Examples include
  - Add multilingual human assistance (e.g., through video, audio, or internet chat via an app or the vehicle's technical interface) to resolve the barrier of lack of trust in automated technology by providing human contact and monitoring throughout the trip and improving ease of use for users.
  - Add signage and audio announcements in vehicles to improve communication with people with hearing and visual disabilities.
  - Initiate collaborations between policy, regulatory, and community groups with AV service providers to implement localized and ADA-accessible pickup and drop-off locations for older adults or people with disabilities to select as start/end locations.
  - Encourage service providers to partner with businesses such as WeWALK, which produces smart canes for people with visual disabilities and hearing aids/Cochlear implants for people with hearing disabilities that could be paired using Bluetooth with AVs to inform users of the vehicle location. It is important to note, however, that smart canes can be cost-prohibitive, so affordable options should be prioritized.
  - Provide real-time data and location, including outdoor and indoor navigation, to help people track their vehicles (during a trip, and at their pickup or drop-off locations) through virtual support stewards.
  - Provide channels to communicate with a caregiver (if applicable) during the ride, provide real-time rider/vehicle location information to a caregiver or family member, or enable audio and/or video monitoring of the ride. These capabilities could help increase rider safety and security perception but also necessitate the introduction of controls for user privacy.

California State University Long Beach (CSULB) (2021) partnered with Uber/Lyft to develop eight pickup and drop-off points on campus and ensured that each is ADA accessible.

- Tappy Guide, a mobile app that virtually assists passengers with disabilities, provides real-time data and location, including outdoor and indoor navigation of the vehicle (Tappy Guide n.d.).
- The assistive technology Microsoft Soundscape Street Preview allows users with visual disabilities to virtually preview locations at the street level via an audio description and build a mental map of these spaces (Microsoft n.d.).

- **Engage community members in the process of vehicle and software design** to ensure that their needs are incorporated from the outset, thereby integrating accessibility into the service from the beginning instead of retroactively making modifications.
  - This strategy may include soliciting input, such as during a shared AV pilot program, from people with different types of disabilities and older adults, on the accessibility of technology and ease of use. Feedback from target populations could help not only meet the needs of diverse riders but also explain the technology and spread awareness.
  - Example areas for accessibility improvements include
    - More accessible/modified vehicles, including low-floor vehicles for easier access and ramps to increase accessible stopping locations.

    - Safe storage options for mobility scooters and oxygen tanks.
    - Improved automated lockdown systems for wheelchairs.
    - Geolocation to consider obstacles on the curb to find an accessible place to stop.
    - Platforms to allow users to input their accessibility preferences, such as the need for WAVs, vehicles with ramps, or extra assistance.
    - User-friendly interface with clear, large icons and intuitive design, to make it easier for individuals with cognitive impairments or limited digital literacy to navigate and use the application independently.
    - Designated storage compartment to accommodate folding wheelchairs, walkers, and other mobility devices. Storage compartments could be strategically located to prevent obstructions or safety hazards during the ride. Individuals using wheelchairs or canes may not necessarily be expected to use the designated storage compartment since their devices are typically essential for their mobility throughout the ride.
- **Advocate for and implement accessible and inclusive vehicle standards** requirements through collaborative partnerships with industry stakeholders, government agencies, and disability advocacy groups.
  - Leverage expertise, exchange best practices, and drive positive change in the industry, ultimately ensuring that new mobility services are accessible to individuals of all abilities.
  - Ensure that future mobility apps follow U.S. DOT accessibility guidelines.
  - Promote universal accessibility and design principles that eliminate the need for an onboard assistant in AVs.
  - Require vehicles used in services funded with public monies to be fully accessible per ADA standards.
  - Require operators to set additional fees in typical rides to fund the implementation of ADA compliance mandates.
    - Shared AV deployment teams could also consider applying for supplemental grant funding focused on improving the physical accessibility of on-demand services for older adults or people with disabilities.

California requires TNCs to collect a $0.10 fee on all trips to support funding to increase the number of WAVs for on-demand services (California Public Utilities Commission 2019).

- **Provide travel training or mentoring programs** that focus on assisting individuals with disabilities or those who require additional support in using new mobility services, particularly future AVs, to support adoption and familiarity with the service. These programs could include, for example, personalized instruction on how to navigate the AV technology, access features, and ensure a comfortable and safe experience.
- **Develop informative outreach materials** such as brochures, fact sheets, or pamphlets that highlight the benefits and functionalities of the new mobility service.
  - Distribute outreach materials through various channels, including utility bill inserts, community centers, disability organizations, or local events.
  - Consider hosting AV demonstrations where individuals could experience the technology firsthand and have their questions answered by knowledgeable staff members.

TT-9: Improve Safety and Comfort for Shared Ride Services

GOAL	Access to Technology Awareness Safety and Security
SERVICE	App-based carpooling services Ridehailing services Fully automated vehicle services
POPULATION	People aged 65 years or older People who speak little or no English People with disabilities People with low incomes People residing in rural areas or on tribal reservations

Overview

Shared ride services, especially shared AVs, are critical for improving access to mobility in underserved communities, but their successful implementation requires addressing various barriers and implementing effective solutions. Some riders have concerns about safety and personal comfort when using existing shared ride services. Due to the emerging nature of shared AV technology and a lack of publicly available information about operational and rider experience specifics, these concerns are prominent when considering all phases of an AV trip. Establishment of robust and effective safety standards and protocols can improve underserved populations' adoption of shared services. The safety and comfort features, trialed and perfected in current technology, will help with setting standards for shared AV services, though specific modifications are needed for future adoption.

Major Barriers

Establishing trust in shared vehicles is a crucial first step among the general public, particularly among populations less inclined to embrace new technologies. Existing shared ride services in ridehailing and carpooling face safety and comfort concerns, especially for night riders, women, and people with disabilities.

A major barrier in AV technology is the lack of trust in driverless vehicles and the related perception of danger. If a potential rider does not trust AV technology, it will likely deter them from attempting a trip. Concerns about the reliability, safety, and performance of AVs contribute to a lack of trust in the technology. Older adults and people who speak little or no English may have limited exposure to information about emerging technologies, including self-driving vehicles. This lack of awareness and understanding contributes to lower trust and willingness to use shared vehicles.

In this project's transformational technologies survey, the following concerns were most relevant to respondents:

- **Lack of trust in AV technology.**
- **Inability to take over in a potential crash situation.**
- **Lack of information about self-driving vehicles.**

The absence of specific requirements for new on-demand mobility services to be universally accessible and ADA-compliant also poses a significant barrier. Moreover, the adoption of shared AVs faces several additional barriers, including cybersecurity and privacy concerns; legal and

regulatory challenges, including liability and compliance with traffic laws; infrastructure readiness, such as upgrading roadways and establishing charging stations; and social acceptance and behavioral adaptation.

Potential Strategies

- **Support the development of on-demand enhanced safety features.** Some examples include
  - Emergency stop button that, in the event of a crash or emergency, causes the vehicle to pull over to the side of the road and stop in the first safe location.
  - Emergency evacuation button to open all doors and activate exit ramps/lifts in the event of a crash or emergency.
  - Emergency assist button that calls 911 and shares the trip with the 911 dispatcher (as an in-app emergency button or one-step voice-activated notification).
  - In-app geographic tracking that alerts emergency contacts or caregivers if the vehicle runs off course and allows them to check in with riders and offer resources to get help.
  - In-app or in-vehicle button that connects riders to a 24/7 helpline where operators can provide instructions, offer assistance, and alert authorities in the event of an emergency.
  - In-app, online, or audio monitoring by a caregiver during the ride—this is especially important for riders who might have difficulty using in-app buttons/support mechanisms.

> Uber partnered with ADT Security Services to offer a feature that allows riders to request help from a safety agent directly in the app if they feel uncomfortable on a trip but are not in an emergency situation. Riders can tap the safety shield icon and get help from a trained ADT agent—either on the phone or silently via text. If the situation escalates, ADT can call 911 (ADT 2021; Uber n.d.).

- **Provide in-vehicle auditory and visual information** regarding stops, trip route, duration, and boarding and exiting instructions to help riders feel safe, secure, and supported throughout their ride. Ensure the features are tailored based on the needs of underserved populations. Examples include
  - Implement monitors that display visual route information and ensure the information is clear and easily readable for riders with auditory disabilities and those who speak little or no English.
  - Explore the use of headphones with audio instructions and narrations (with supportive designs for riders with visual disabilities or older adults), considering the logistics of sharing headphones in a shared vehicle environment and ensuring they are safely stored and easily accessible.
  - Display clear signage in multiple languages throughout the vehicle to assist people who speak little or no English in understanding the information.
  - Provide in-vehicle or in-app translation capabilities to facilitate effective communication between attendants and riders who speak little or no English, addressing any potential limitations and ensuring the system is user-friendly and reliable.
  - Assist riders exiting shared AVs in an unknown or unexpected location with apps, including features specifically designed to meet the needs of individuals with auditory, visual, ambulatory, and cognitive disabilities as well as older adults.

> In major cities in Oklahoma and Texas, SendaRide operates an on-demand ridehailing service that connects patients to medical appointments and emphasizes safety and comfort for passengers by allowing riders to provide special instructions to drivers regarding needs (SendaRide 2021).

- **Include internet availability in new mobility service vehicles** to allow continued smooth ride operation and continuous location sharing and enable riders to report any issues or emergencies, ensuring passenger safety and timely response.
  - Explore opportunities to collaborate with internet service providers or use mobile network technologies to equip their vehicles with reliable and secure internet connectivity. This may involve installing Wi-Fi hotspots or using cellular data connections, depending on the infrastructure and coverage in the operating areas.

- **Require formal training or certification programs** for in-vehicle attendants to complete, such as the PASS driver certification program (Community Transportation Association of America n.d.), to provide help, assistance, and direction to riders if they request additional assistance.
- **Standardize a universal internal vehicle design for shared AVs** that prioritizes comfort and safety for all regardless of their age and ability.
  - To assess the effectiveness and impact of design, technology, and accessibility measures, implement active survey cycles to gather feedback and monitor prevalent concerns, identify areas for improvement, and make informed adjustments to enhance the overall user experience.
  - Prioritize feedback from target populations to ensure specific needs and challenges are addressed, ultimately leading to a more inclusive and user-centric design.
- **Use targeted education or marketing campaigns** to provide more information about vehicle safety features and emergency protocols. This information should be provided in various formats to improve reach (e.g., printed text, in-app or social media, radio ads, in-vehicle auditory announcements, or community events).

TT-10: Promote Equitable Implementation of Shared AV Services

GOAL	Availability
SERVICE	Fully automated vehicle services
POPULATION	People who speak little or no English People with low incomes People residing in rural areas or on tribal reservations

Overview

As an emerging technology, shared AV deployments hold the potential to increase access to opportunities in underserved communities, especially through connections to other transportation infrastructure. However, the high costs associated with designing, building, and deploying services like shared AVs create a risk of prioritizing deployment in high ROI environments, potentially excluding underserved communities. Enabling a dramatic paradigm change involves considering the communities with the highest need to foster equitable access and implementation. Implementing a comprehensive approach that combines prioritized deployment in underserved communities, proactive measures to prevent discriminatory biases, and integrated transit-service shared AV deployments will be critical to promoting equitable access and integration and enhancing opportunities for all.

Major Barriers

Barriers to the implementation of new technologies and infrastructure improvements, including early deployments or pilots of shared AVs, are influenced by several factors. One significant challenge arises from the inadequate state of existing infrastructure, which may demand large investments for repairs and upgrades. This issue is particularly prominent in poorer regions that lack sufficient budgets for large-scale initiatives, making it less appealing for shared AV operators to allocate early deployments to these challenging and less lucrative areas, such as rural and tribal areas.

As shared AVs become more prevalent, there is a risk that operators will prioritize densely populated areas with wealthier riders, excluding underserved populations with limited transportation options and facing historically discriminatory planning practices. These practices, such as favoring highway construction and suburbanization, have gated low-income communities and communities of color in resource-limited neighborhoods, exacerbating transportation disparities.

Furthermore, current shared AV deployments mainly focus on fixed routes often serving specific areas like entertainment districts and college campuses, disregarding populations requiring adaptable travel needs such as flexible pickup and drop-off locations. Additionally, they tend to concentrate in wealthier urban service areas, leaving rural and tribal populations with higher travel costs and increased isolation.

Another barrier is the lack of effective connectivity between shared AVs and existing transportation infrastructure. While shared AVs can potentially increase access to opportunities, their current implementation often fails to establish seamless connections, particularly for transit-reliant populations. Isolated shared AV services, without integration with affordable transportation modes like public transit, can be inaccessible for those relying on transit.

Potential Strategies

- **Deploy shared AVs as an integral component** of the transportation environment.
  - Ensure that transportation transformation includes continued investment in accessible transit and active transportation infrastructure.
  - Ensure that shared AV fleets are connected to existing transportation infrastructure to provide connections to other modes.
- **Explore the potential to coordinate planning and funding** through contracted partnerships. Operators are unlikely to lead efforts for transportation equity, so agencies and policymakers must make firm decisions. Transit agencies and shared AV providers can work together to
  - Evaluate riders' personal travel costs during deployments to preserve access and affordability for low-income populations and people with disabilities.
  - Target deployment in low-income areas and those with high concentrations of populations of color.
  - Improve design and operations during service expansions, thereby saving costs.
- **Seek grant funding** focused on improving accessibility for low-income and minority populations to reduce the cost of operating in these areas and to enhance the transparency of shared AV algorithms that improve service equitability and reduce existing biases.
- **Understand existing service gaps** and local socioeconomics before deployment to ensure that chosen routes and service areas (for flexible services) prioritize service for underserved populations.
  - Incorporate underserved communities in planning processes to prioritize connections between shared AVs and existing travel service networks and other modes.
  - Keep in mind that information sharing, sourced from local agencies and groups, shortens the timeline for planning. Shared AV operators can pledge to publish or share ride information as a mutually beneficial partnership between community groups/agencies and operators.
- **Launch educational campaigns** in shared AV operator and transportation organization partnerships to allow for low-income and minority riders to provide feedback on the efficacy of current efforts.
- **Track performance** and continually evaluate biases.
  - Require performance metrics reporting of shared AV ridership of private operators in cases of public-private partnerships to monitor and ensure that operations are equitable. The geography of trips as well as the socioeconomic indicators of the geographies should be examined.
  - Ensure app rider-matching algorithms are unbiased toward geography and neighborhood selection through policy requirements for shared AV companies.
  - Prevent rider discrimination by minimizing personal rider details such as names and photos in shared AV ride-matching and when alerting riders of shared pickups.
- **Implement effective code enforcement, traffic monitoring, and infrastructure maintenance** so that the infrastructure in the area being served is in sufficiently good condition [no missing signs, no double-parked cars, or other challenges to the operating design domain (ODD)] and well-mapped to support the ODD of the vehicles in an equitable and safe manner. Rural and low-income areas may have especially poor infrastructure, such as limited sidewalks and

- Denver's Department of Public Works requires carshare companies to place vehicles in areas with 30% or more of the population below the poverty line (Kodransky and Lewenstein 2014).
- LADOT's electric carshare program BlueLA strategically places vehicles in low-income communities of color (Blink Mobility n.d.).
- To increase mobility in rural New York, Tompkins County received funding to develop a Mobility as a Service model based on large collaborations between public and private providers (National Center for Mobility Management 2022).

A deployment operation in the Netherlands is developing a more equitable trip-matching algorithm that diverts AVs in wealthier areas to underserved areas using artificial intelligence (TU Delft 2021).

right-of-way obstructions, due to regional, state, and federal disinvestment and limited local resources.

- Weigh the impacts of enforcement measures to avoid exacerbating existing inequalities or disproportionately targeting certain communities. By doing so, the strategy should aim to improve the conditions of infrastructure in the area being served while maintaining a balanced and equitable approach.
- Consider exploring alternative methods of enforcement that prioritize community engagement, transparency, and accountability to address infrastructure issues without further burdening underserved populations and avoiding any potential biases or disparities in law enforcement practices.

CHAPTER 4

Implementation Considerations

In the effort to eliminate barriers to accessing transformational technologies, having a clear understanding of the service intent and the boundaries within which the service operates is essential. This understanding must be gained through the perspectives of those being served and in the context of what can be achieved with available resources. Obtaining this understanding must be a key part of the implementation policy in every case.

The implementation considerations checklist (Table 5) outlines actions that must be considered not only to achieve long-term success but also to manage expectations and maintain the credibility of the implementing organization. There may not be simple methods for executing the actions and easy answers to addressing challenges, such as regulatory compliance, funding sustainability, and user adoption, but it is crucial to address these challenges for the mobility service program to be successful.

This chapter was developed as a complementary tool to the plays and should be used alongside them. Considerations appearing here apply broadly to all programs and new and future mobility services.

Each of these focus areas listed in Table 5 is further expanded on in the subsequent sections. In addition to these implementation considerations, when deploying a strategy, it is essential to consider both the duration and cost of the project. Following a discussion of the key focus areas listed in the table, this chapter delves into the importance of project duration and cost, providing insights into the factors that influence their determination and potential strategies to be considered.

Overall Program Needs

Defining overall goals and identifying opportunities and constraints for program deployment are foundational steps for a successful program. A program is laid out in a specific region with its spatial arrangement, economy, weather, infrastructure, and people. Establishing goals and understanding opportunities and constraints can therefore not be done accurately without early community engagement.

Traditional transit systems have focused on transporting commuters in and out of employment hubs, but many trips fall outside this context. Thinking within the target underserved community's context will include thorough envisioning of daily life, noting food insecure areas, where people go to get medical care, location density of jobs, and typical work hours. Late-night services will have to carefully manage safety concerns for riders.

Heavy emphasis should be placed on determining project goals collaboratively so as not to waste energy and resources on pilot programs with a low chance of success. Understanding the

Table 5. Implementation considerations checklist.

Focus Area	Consideration
Overall Program Needs	• Solicit input from underserved populations to enumerate their wants and needs through a community outreach effort and actively work to ensure the findings are understood by all relevant parties. • Determine applicable underserved populations for trips and trip types. • Assess the sustainability of a pilot program and determine the appropriate next steps for its permanent deployment if the pilot program is successful. • Understand the barriers outside the traditional transit/transportation arena (e.g., spatial mismatch where jobs are located and where people live, resulting in transportation barriers that can make it difficult for people to access employment opportunities). • Determine which entity or entities are best positioned to lead/fund the effort (or parts of the effort). • Ensure the program is set up to react to changing needs by enabling flexibility. • Establish a program-specific set of performance measures, specifically designed to check whether the objectives (e.g., increasing access for people with low incomes) are met.
Communication and Adaptation	• Ensure appropriate setting, medium, and language (e.g., accessibility for people with cognitive, hearing, or vision disabilities and people who speak little or no English). • Implement and/or expand call center operations to support access to a variety of services, including concierge for trip planning, booking, complaints, training, and payment. • Be prepared if the program does not meet expectations and document the lessons learned to be able to try again. • Prepare a plan for managing a significant negative event (crash, criminal act). • Understand that crashes involving emerging technologies (as in the case of AVs) have a very high media profile—be prepared and transparent. • Audit and assess accessible service quality.
Funding Approaches	• Assess the available budget and funding resources for building an effective program and rely on a realistic assessment. • Assess the potential long-term costs and level of control over program decision-making before establishing partnerships.
Compliance	Ensure full compliance with • Property/fiscal accountability. • Federal reviews and procurement regulations. • Drug/alcohol testing. • Accounting. • Accessing detailed operational data. • Recordkeeping and privacy. • Insurance and liability considerations. • Requirement of an attendant to be present in a vehicle (if applicable) or capability/option.
Vehicle Autonomy	• Understand current gaps and barriers for underserved populations and design shared AV solutions to improve them, not ignore them. • Assess and verify the adequacy of the roadway and wireless infrastructure in rural and tribal areas before implementing any deployments. • Adopt industry standardization of emerging technologies. Standardization will facilitate vehicle-to-infrastructure/vehicle-to-vehicle communication, improve the ODD, and improve safety. • Set and enforce standardized AV frameworks and communication links. • Develop and require accessible vehicles.
Private-Sector Implications	• Work to overcome company resistance to equitable service areas and accessible vehicle offerings. • Leverage existing services to better use existing transportation capacity. • Adapt existing policies and governance to provide solutions to barriers. • Improve inclusiveness for all potential rider groups. • Improve equity/accessibility needs by closing gaps in area coverage and offering broader access for underserved communities. This targeted approach may offer a means of additional funding opportunities from specific grant programs.

Table 5. (Continued).

Focus Area	Consideration
Other Specific Factors	• Ensure effective land use planning to proactively mitigate equity or accessibility issues from developing. • Consider how children's car seats and other needs (e.g., baggage) will be accommodated. • Consider how young children will be accommodated (e.g., how will they be safely secured in or on a vehicle, and how young is too young to ride alone?). • Ensure app-based driver and passenger ratings are assessed for bias during interpretation of feedback data.

environment residents live in, including its terrain, weather, and recent court and policy decisions, will make for a more realistic design. Pilot programs should be designed with specific performance measures, including equity metrics, and a vision for a full, long-term deployment if successful. Preparing for success involves leaving room for adaptations and lessons learned from the pilot.

Key questions to be answered during the program design phase include the following:

- What do the underserved populations want and need? What is the best way to engage with them and develop a responsive relationship?
- How does the program fit into the existing transportation environment? How will trips be streamlined to avoid burdening travelers with excessive transfers and complexity?
- What kind of trips will the service be fulfilling, and for whom? Where are the jobs and what are their working hours? Are work trips a key issue for the population being served (as opposed to other travel purposes)?
- Is there availability of shopping and other services close to home? What is the availability/cost of delivery services? Where are the locations of medical facilities or alternative options such as urgent care centers and walk-in clinics?
- Are there barriers outside the traditional transit/transportation arena that can present additional challenges to future success?

Communication and Adaptation

Communicating with the public and adapting in the case of problems, failures, or negative events go hand in hand. Establishing reliable sources of information, with frequent and clear messages communicating changes in the program and responding to problems, is needed to reduce misinformation.

Communication avenues provide more than mere information dissemination; they act as opportunities for potential riders to voice concerns and build a relationship with the agency or service operator. The following should be considered:

- **Setting.** Communication settings should be appropriate for people with nonstandard working hours, family care pressure, and transportation challenges. A central location to the service area or another location that is well-known, easily accessible, and where participation can be achieved is appropriate. In-person meetings are important in assessing the needs of persons with cognitive disabilities and their caregivers.
- **Media.** Modes used for communication should be varied and accessible to reach a maximum number of people, including people without smartphones and people of all disability types.

- **Language.** Selection is key, such as providing non-English communication in some communities, as well as ASL and braille. Some people with cognitive disabilities may require communication through their caretakers.

With open channels of communication, in case of a negative event like a crash or criminal act, established avenues can be used to address the situation. There is no worse day in the life of an agency leader than the day any of the people being served are seriously injured or killed. Such events can quickly heighten emotions and cause rash actions that can end what could be an effective program. Plan to

- Identify who will be the spokesperson for the program to media and public calls. The National Incident Management System has excellent planning tools and protocols. Answering media calls after establishing a clear understanding of the event and a go-forward plan is most effective.
  - Follow the investigation closely and report on any updates or developments as they become available.
  - Be transparent and thoroughly explain the event, including the involvement of technology (if any).
- Determine the immediate action in the absence of a clear understanding of the event.
  - Complete an investigation and reveal that the agency is doing so. Understanding the full incident before giving a formal statement will prevent miscommunication and a potential loss of credibility.
  - Consider a 2-day safety stand-down to evaluate program processes, but state that the program will return to operation at the end of the stand-down unless contrary facts emerge.
- Address failure of an inexperienced operator to meet program requirements. Sometimes an implementor gets beyond their capability and fails to perform. There will be pressure on the city or transit authority to take over the operations. Agency leaders should know upfront if this is a possibility or clearly state it will or will not happen, while understanding the required steps to unwind a contract, dispose of assets, and so forth.
- Understand and identify risks concerning the implementation of AV technology. Media and public opinion are very sensitive to even rare AV mishaps, which have derailed promising programs. Plan carefully for the implementation of AV technology.

Outside of major negative events, stakeholders, operators, and agencies should have commonly understood metrics for the success of the program, including trips completed, populations served, cost per rider/trip, service gaps eliminated, key destinations served, jobs accessible, grocery stores accessible, healthcare facilities accessible, service availability/frequency, on-time performance, and level of service equity. Riders should have access to a multilingual call center that takes payments from debit or credit cards, reserves rides, and provides ride details to riders without a smartphone.

Accessibility can easily fall short in practice from what may have been decided during design phases. To protect the quality of service for all riders, regular audits and assessments of service will help identify accessibility gaps that need to be addressed. This should include seeking direct input from users, community members, and stakeholders regarding the implementation of new mobility services.

Key questions to be answered for communication and adaptation include the following:

- Who are the stakeholders? With what setting, mode, and language can they best be reached? Which groups are not represented at outreach events?
- Who will oversee communication in light of a negative event? Who will speak to the media? How and when will community questions be answered?

Funding Approaches

Being able to roll out an effective program is contingent on a realistic assessment of the available budget and financing options. The funding and operational model chosen (i.e., publicly owned and operated, publicly funded and privately operated, privately owned and operated) can change costs and operational decision-making for programs. Agencies should carefully weigh the potential long-term costs and level of control over program decision-making before entering public-private partnerships.

For example, in the case of accessible ridehailing programs, funding can take two approaches:

- **Private-Sector Lead.** Ridehailing services (with drivers or automated) can address the needs of underserved communities (people with disabilities in particular) by providing service in underserved areas. Funding can be provided for accessible service at the same times and locations by contracting with the traditional rideshare company model (driver-owned vehicles) or through an added fee if they do not provide accessible vehicles.
- **Public-Sector Lead.** The challenge of lagging service implementation can be addressed by integrating this solution into existing public transportation services. This approach can effectively meet community needs that are challenging to address with traditional transit options or in areas where private-sector offerings are lacking. Funding for this initiative can be generated through fees collected from ridehailing services, which can be specifically allocated to improve accessibility for people with disabilities and extend service availability to areas without shared AVs. Depending on regulatory requirements, public incentives may also be considered in conjunction with private funding solutions. This combined approach ensures a comprehensive and sustainable implementation strategy.

Funding is often led by governmental entities but can make use of the private sector, social services, and religious groups to delegate the coordination and operation of programs. Partners should be carefully evaluated for their capabilities and skills.

Key questions to be answered for funding include the following:

- Who is best positioned to lead and fund the effort, or parts of it?
- What is the long-term cost-effectiveness of a private versus public funding mechanism? What are the advantages and disadvantages of public, partnered, or private service coordination?
- Can the implementation model be changed to serve underserved communities first or concurrent with high ROI services?

Compliance

Funding scenarios for these programs often come with strict requirements for recordkeeping. The implementor must be able to demonstrate good attention to detail for the funds. The Triennial Review and Title VI Review, procurement process guidelines, drug/alcohol testing, and accessibility in shared AVs through attendants must be prepared for as part of federal regulation compliance. Other requirements include

- Property and fiscal accountability, equipment maintenance, property and personal data security, work standard adherence for contract performance, advanced planning for smooth operations through contract renegotiation and personnel changes, software licensing, cash handling, payroll, and tax payments must all be handled effectively to maintain good business standing.

- Detailed data sharing between contracted operators, like TNC services, and transit agencies is required for the National Transit Database and for an accurate evaluation of program performance. Before entering into contracts, understand what, if any, limitations on data availability are present and ensure that data needed for compliance and performance metrics will be available and not restricted by proprietary limitations.
- Data protection for riders is especially important for underserved populations.
- A robust accounting system may be necessary depending on the source of funds and agency requirements.
- Adequate insurance policies are necessary to protect sponsors, staff, and riders from liability risks.
- Licensing and permitting of vehicles by appropriate local and state authorities is needed, especially for operation of AVs.

Federal procurement regulations may exceed prior expectations and may be difficult to understand and plan. Although some nonprofits and faith-based organizations may be exempt, noncompliance will limit opportunities and flexibility in the long term for the program. Care must be taken to meet requirements from all funding partners and governing entities—federal, state, local, and sponsoring private entities. Small purchases, contractor involvement in purchasing, and Buy America provisions are areas to watch. Processes, recordkeeping, and personnel authorizations should be established before purchasing begins.

Drug/alcohol testing is often a difficult issue for ridehailing companies. This issue is further complicated by prohibited substances that may well be legal in the state in which that program operates. The implementor needs to understand if testing will be required when making all hiring and contracting decisions.

Key questions for maintaining compliance include the following:

- What reporting requirements is the program subject to from local, state, federal, and private sponsors?
- What are the procurement process requirements for the program? How will contracted partners be held to these standards? Who will keep track of procurement?
- What data are required for accurate reporting to the National Transit Database? How will data be shared between contracted partners and agencies?
- How will ADA compliance be maintained with new technologies? Is accessibility included in all stages of program development?
- What drug and alcohol testing protocols will be used? For states with fewer substance restrictions than federal law, will testing be required?

Vehicle Autonomy

AVs face challenges in areas without wireless broadband connections, which is of particular concern in rural and tribal areas. Pressing for broadband expansion is needed to include these areas in the eventual shift toward (shared) AVs. Thorough vetting of a service area must be done to ensure there are no gaps in service coverage and that rigorous addressing is in place to permit GPS use.

Standardizing the AV framework and communication links with roadside equipment is essential. Infrastructure development should facilitate the needs of AVs and their passengers while protecting other road users, especially pedestrians and cyclists. Regulators can push for standardization and proactively develop roadside infrastructure that maintains safe, equitable

road standards for all road users. Standardization efforts should address electric vehicles' communication needs with other vehicles and the roadside [vehicle-to-everything (V2X)], improvement of accessibility beyond minimum requirements, shared operation, passenger communication, emergency signals/stops, ingress/egress controls, and so forth. With new technologies, service models and vehicle types may not fall under existing regulations. First responders' access to vehicles for medical emergencies or rescue from fire and collisions must be ensured for safety.

The full impact of Levels 4–5 shared AVs must be understood before programs are developed and deployed. Table 6 illustrates how current transportation problems for underserved populations riding in shared, human-driven vehicles (SAE Levels 0–3) could be improved, worsened, or unaltered by the introduction of higher levels of autonomy.

Table 6. Impact of shared AV implementation on barriers to underserved populations.

Index Icon	Barrier Increased with Shared AVs	No Change with Shared AVs	Barrier Decreased with Shared AVs
		Presents same barriers related to affordability, banking access, and smartphone/data access (banking and internet/data inaccessibility).	
	Increases real or perceived risk from other passengers with no driver to summon help or intervene. May increase feeling unsafe due to discomfort with the technology.		Removes the impact of human error in driving. Removes real or perceived risk from the driver.
	While similar to systems with drivers, the risk of population or location bias in the assignment system due to profit level may increase risk if not addressed.		Removes the risk that an individual driver will deny service to any individual or fail to serve an underserved area due to bias. In microtransit applications (including a more expanded route with improved shared AV technology), shared AVs may increase connections to transit and other transit options. If realized, lower operating costs may expand the ability to serve broader populations.
 	The introduction of autonomy adds further complexity and concern. No driver is present to answer questions from unfamiliar riders. No driver is present to help, recognize the need for assistance, or identify accessible loading/unloading locations (e.g., poor surfaces like gravel or high curbs, which are likely a greater issue in rural areas without paved sidewalks).		Demonstrated success in the application may be the most effective way to improve trust in technology by potential riders. Asynchronous shared AVs improve independence for people with disabilities, including people with visual or mobility disabilities.

Private-Sector Implications

Private companies are unlikely to lead transportation equity efforts since the profit model leads them to prioritize efficient, high-return geographies first. However, agency structure and the increasing sophistication of transformational technologies open opportunities to facilitate broader access.

Government entities can take several levels and types of action, including forced compliance through ordinances and statutes requiring availability and accessible accommodation. Other options include incentivized compliance and provision of a parallel alternative through a transit authority to underserved areas. Enhanced provider collaboration, like automatic routing through an alternative service provider, can reduce the burden on riders, especially when requesting accessible vehicles. However, making accessible vehicles widely available in all services should be a priority.

Additional considerations include leveraging the investment by private- and public-sector entities in service technologies through the use of existing technology applications. There is no need to reinvent processes that are available off the shelf. Creative uses of existing vehicle capacity, like driving commuters who can act as a last-mile connection for their coworkers, could be seen as a jobs program or a source of extra income.

Key questions regarding private-sector considerations include the following:

- What kind of relationship do government entities, private service providers, and resident populations have? What are some likely points of conflict?
- How much leverage do government entities have to guide private operators? Are there current legal challenges at the local or state level? Are there imminent policy changes that could affect service design and deployment?
- How much new technology investment is necessary to meet a region's travel needs? Can current vehicles and infrastructure be used differently or more effectively?

Other Specific Factors

Some challenges are difficult for an implementing agency to influence or resolve. Land use planning or the spatial arrangement of a city or region is outside the scope of an individual transportation service. Disconnected growth of economic opportunities and housing availability crossing over multiple jurisdictions can make service planning complex. Since COVID-19, transit ridership has not yet fully recovered, and commuting travel patterns have changed or outright decreased (including changes related to work-from-home trends). In a post-COVID travel landscape, programs should adapt to shifted travel behaviors.

In many areas, there is not one overarching transportation authority to provide service. Allowing fare sharing across boundaries (GoPass—DART/DCTA/Trinity Metro) is nontraditional but can encourage the hesitant/long-commute riders to expand their trip-planning horizon. Fare sharing can also ease barriers in educating riders to use different neighboring services at different rates.

Parents and guardians must often travel with small children, and older children may want to use services. Their inclusion into service must be decided but will ultimately be affected by parental guidance and cultural norms. The provision of car seats and helmets as well as the decision to include or exclude children from a program will be part of an individual program's implementation. Passenger cargo must also be given a space in program and vehicle design.

Finally, it is important to ensure that app-based driver and passenger ratings are assessed for bias during the interpretation of feedback data. Highly-rated passengers can be routed first to highly-rated drivers. There is a potential for bias to enter into this rating system. Much like restaurant or product reviews, this potential must be acknowledged in the interpretation of feedback results.

Key questions for outside factors include the following:

- What experience and resources do neighboring agencies have? How can transformational technology services build on each other, especially in dense, multi-municipality regions?
- How prevalent is hybrid work? Are there signs of change to hybrid work arrangements from major employers?

Deployment Duration and Cost

When deploying a strategy, it is essential to consider both the duration and cost of the project. This section delves into the importance of project duration and cost, providing insights into the factors that influence their determination and their impact on successful strategy deployment.

Duration Considerations

It is important to consider both technology and policy aspects across different timeframes for effectively implementing mobility strategies and ensuring a smooth transition toward transformative technologies. The following subsections explore the short-term (6–12 months), medium-term (12–24 months), and long-term (24–36 months) perspectives.

For each timeframe, specific technology and policy considerations are provided, taking into account factors such as software deployment, customization, equipment deployment, resource acquisition, training, stakeholder engagement, infrastructure assessment, and legislative actions. Furthermore, because Levels 4 and 5 AVs are still in development, this discussion also highlights the enabling factors that will contribute to their eventual deployment in a manner fitting the needs of all.

Short-Term Strategies

Technology considerations for short-term strategies are

- Procuring and deploying software as a service, commercial off-the-shelf, open source models.
- Examining the potential role of an agile method that emphasizes iterative and incremental development, continuous feedback, and adaptability to changing requirements. In other words, incrementally deploy functionality in smaller, incremental releases over time rather than wait until the entire software is complete. This approach allows agencies to deliver working software more quickly, get feedback early, and make improvements throughout the development process.
- Owning (or subscribing to) equipment (e.g., cloud) to operate the software.
- Leveraging existing services that operate technology (update system configuration parameters)—for example, add to an existing call center to manage new mobility operators or services (bikesharing, ridehailing, etc.).

Policy considerations for short-term strategies are

- Expediting procurement (or making procurement available through the schedule, purchase order, or task order).
- Ensuring that policies related to operating the mobility solution are available and have the support of legislators/policymakers where appropriate.
- Preparing agreements or memorandums of understanding (MOUs) with associated stakeholders, including individuals or organizations that play a significant role in the operation or implementation of a particular program or initiative (e.g., independent owner/operators who may have unique perspectives or concerns that need to be addressed in the agreements or MOUs).
- Providing resources to educate and train staff and users on service.
- Ensuring that awareness is built with input from underserved communities on their needs from the services.

Medium-Term Strategies

Technology considerations for medium-term strategies are

- Making limited software customization to an existing system (requires coding and software updates).
- Deploying equipment in the field or on premises.

Policy considerations for medium-term strategies are

- Acquiring resources, operations training, and maintenance personnel to start up a new system with new staff.
- Establishing new MOUs for sharing information.
- Setting up funding for deployment sustainability.
- Engaging stakeholders for pilot feedback.

Long-Term Strategies

Technology considerations for long-term strategies are

- Developing, prototyping, piloting, and deploying a system.
- Examining higher resources and skilled labor needs for syncing operations with new technology.

Policy considerations for long-term strategies are:

- Establishing new MOUs that include settlement and financial reconciliation (e.g., deployment governance of multiple organizations).
- Passing legislation or acquiring a waiver to allow mobility vehicles to operate (e.g., e-bikes, e-scooters, AVs).
- Performing realistic assessments of the state of infrastructure and regional preparedness for transformational technology additions. Many regions, like rural and tribal areas, will need sustained investment into repairing and upgrading infrastructure before spending money on new technologies.

Policymakers play a crucial role in the successful deployment of emerging technologies, understanding that the mere development of these advancements does not automatically ensure their availability in every region. It is essential to recognize that the adoption and implementation of AVs, including shared AVs, are contingent on factors such as infrastructure preparedness, labor costs, and public readiness. Acknowledging these considerations is pivotal in formulating effective policies that align with the unique characteristics and requirements of different regions. Table 7 provides a summary of enabling events and conditions for shared AVs.

Table 7. Shared AV implementation enablers.

Enabling Event/Condition	Description
Lack of Driver Availability	The consistent lack of drivers (low unemployment, competition for more favorable jobs) will impact the ability to staff the traditional shared services.
Driver Cost	Changes in collective bargaining rules, the status of employee versus contractor definitions, or other fundamental changes to the ridehailing business model could greatly impact driver costs.
SAE Level 5 Achieved (all conditions)	The broad availability of commercially viable Level 5 AV systems is necessary for the widespread adoption of shared AV services. All issues, including communication, insurance, and liability, must be resolved.
Broadband Communications/V2X/ Edge Computing Available	Overcoming latency and bandwidth issues is key to successfully having a shared AV react quickly enough for unusual or unexpected situations (e.g., a pedestrian stepping out of the shadows). This may require the roadside or other vehicles to communicate with the shared AV (e.g., traffic signal change, presence of pedestrians near the road, collaboration from other vehicles) for the reaction time to be short enough for dependable operation. This communication may be a challenge in rural and tribal areas with limited wireless service. The base technology in the vehicle may exist, but the supporting technology to enable SAE Level 5 autonomy may not be present.
Effective Risk Management Established	Clear enabling statutes, insurance, liability regulation, and all other legal issues must be settled by enough states and localities to support a critical mass of vehicles for manufacture at SAE Level 5 autonomy.

Cost Considerations

Assessing specific costs for new and future mobility services can be highly challenging. This complexity is particularly evident in the case of emerging technologies, such as AVs, where cost estimations are still uncertain. Additionally, the geographical context plays a significant role in cost considerations. Therefore, for this research project, comparative measures and the current state of the technology were used to assess cost implications.

Agencies and operators possess valuable insights into their budgets, areas of expertise, and access to specific resources. Therefore, they are best equipped to conduct detailed cost analyses tailored to their strategies and circumstances.

Low-Expense Strategies

Low-expense strategies allow for quick implementation and use of existing technology without altering the price of service per rider. They provide an opportunity, for example, to enhance safety features, promote fare sharing, and raise public awareness through software updates to transformative technology apps. By leveraging readily available solutions, these cost-effective strategies offer an efficient means of improving the accessibility and inclusivity of mobility services.

Moderate-Expense Strategies

While requiring a greater investment than low-expense strategies, moderate-expense strategies offer additional benefits through the integration or adoption of technology that may not be readily available. For example, by implementing a unified transit fare system across various modes, digitizing rural road infrastructure, and enhancing amenities for micromobility riders, these strategies facilitate seamless mobility experiences and address specific challenges in transportation networks.

High-Expense Strategies

High-expense strategies rely on technologies that are still under development and may require substantial investments and longer implementation timelines. Costs in this category can be

unpredictable, such as determining liability insurance for shared AVs, which depends on policy considerations and the stage of shared AV availability. Despite the uncertainties in costs, high-expense strategies offer the potential for transformative impacts. Example strategies include enhancing roadway and digital infrastructure to accommodate emerging mobility services and procuring adaptive shared AV fleets. While costlier, these strategies contribute to long-term advancements in mobility, addressing congestion, enhancing safety, and enabling efficient and sustainable transportation systems.

CHAPTER 5

Conclusion

Technological advancements bring both opportunities and risks to mobility, particularly for historically underserved populations and other populations who face challenges in accessing transportation options. Recent years have witnessed the rapid emergence of shared and on-demand mobility services driven by economic, environmental, and social forces. These services, ranging from micromobility options to car-based services and ridehailing platforms, have gained significant popularity and have become mainstream. Shared AVs also expand the realm of shared mobility options by incorporating automation into various transportation modes, such as microtransit, on-demand, and taxi services. This capability not only mirrors the services provided by human-driven shared mobility options but also extends the reach of AVs to address service gaps for underserved populations.

Although these new and future mobility services offer numerous benefits, there is a concern that they may further exacerbate disparities, thus isolating diverse populations and leaving them behind. Failure to address the needs of these populations in transportation planning can perpetuate historical, institutional disenfranchisement. Thus, the objective of this study was to provide guidance to achieve inclusive mobility, with a focus on ensuring that underserved communities benefit from technology-enabled mobility services. Exclusion from new mobility is not a given and can be avoided with strategic implementation.

The playbook provides solutions to ensure inclusive mobility and improve transportation equity within the rapidly changing transformative transportation ecosystem, thereby helping address the critical need to ensure that transformative technologies do not further widen the gap between the haves and have-nots. The playbook provides actionable guidance, data-driven insights, and metrics to inform decision-making processes for achieving inclusive, equitable transportation and enhanced access to technology-enabled mobility services. The guidance provided in the playbook was informed by an understanding of the historical exclusion and marginalization of mobility options and emphasizes current initiatives and strategic plans. The focus is on how to include historically underserved populations in mobility enhancements, such as smartphone apps, vehicle automation, and shared on-demand mobility services. Through this research, public and private entities can actively work toward transportation equity and ensure that the benefits of transformative technologies are accessible to all members of society.

This playbook and its supporting projects recognize that **addressing inclusive mobility is an ongoing and continuous process.** The playbook emphasizes the importance of conducting regular evaluations to stay attuned to shifting needs and barriers. By proactively responding to these changes, decision-makers and practitioners can ensure that the strategies and interventions remain effective and responsive to the evolving landscape of inclusive mobility.

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APPENDIX A

Literature Review

Appendix A presents the literature review conducted to explore how historically underserved groups interact with transformational transportation technologies. Each section includes information and insight, where available, regarding the future of automated mobility. Although the modes in question are not currently automated on a large scale, trends suggest each will adopt some level of automation as that technology improves.

The review is organized into sections as follows:

- Historical Transportation Inequities and Barriers: This section discusses the history of transportation inequities and barriers faced by marginalized and underserved groups to promote a better understanding of the impacts of new technologies.
- Use of New Mobility Options by Underserved Groups: This section examines the use of select transformational technologies with a focus on underserved communities. As an emerging technology, this section also explores the impact of automated vehicles (AVs) and shared automated vehicles (SAVs) on the transportation system.
- Factors Preventing Access and Use: This section highlights spatial, temporal, economic, physiological, and social barriers associated with transformational transportation technologies and new mobility.
- Inclusion-Focused Policies and Goals for New Mobility: Much of the work to improve inclusion in new mobility stems from the policy. This section explores some of the policy goals that have been implemented at different levels of government before outlining specific policies that either improve or limit access and some of the performance measures that can be used to gauge progress toward higher levels of inclusion.
- Infrastructure for New Mobility Options: Often in response to inclusion-focused policies, infrastructure can improve inclusion in new mobility [ranging from better internet networks in rural areas to accessible vehicles in transportation network companies (TNC) service]. This section outlines findings related to new mobility infrastructure.

Historical Transportation Inequities and Barriers

In the United States, transportation access and ease are inherently imbalanced and inequitable due to various contributing factors, including the country's foundational crimes (e.g., colonization and slavery) and public decision-making influenced by market-based outcomes. As a country, the United States was established on values that emphasized separation and inequity—ranging from the exploitation of enslaved people and land theft for territorial expansion to governmental messaging arguing certain immigrants are criminals or less worthy of citizenship and that women are overly emotional objects with limited personal agency. These conditions have resulted in a tradition of "negative and dehumanizing stereotypes about women and people of color . . .

in the news media and in popular culture" that persists to this day (Osta and Vasquez, 2019). Such conditions limit the representation of communities (e.g., indigenous people and people of color; people with low incomes; immigrants; people with disabilities; women; LGBTQIA+ individuals) that have been traditionally and strategically disadvantaged in decision-making processes, fuel implicit biases, and provide the foundation for structural inequity in all aspects of American life (Marshall-NeSmith et al. 2019; McKittrick 2011; Powell et al. 2019; Sheller 2013, 2018).

Arising from the control required to maintain an economy that functioned from slave labor and a society that required some to suffer so others could prosper, American urban planning, a key factor in access to transportation services, has a "racist history" (Jauregui 2020). This history includes redlining and other government programs to control where Black people live and policies and practices that strategically underdevelop and disinvest in ways that have disproportionately and sometimes specifically targeted communities of color (Jauregui, 2020; Osta and Vasquez 2019; Sheller 2013). The urban renewal practices of the 1950s and 1960s built highways through communities of color and low-income neighborhoods and created precedence that informs ongoing policies and practices and has "led to the destruction of thriving neighborhoods, eviction of minorities, and negative health effects" (Sanchez et al. 2003).

In America, access to transportation—both traditional and emerging modes—is frequently predicated on one's representation among decision-making stakeholders, influenced by implicit biases, and controlled by the structural inequities that form the foundations of governance and society in the United States. Table A-1 presents definitions of these terms.

Barriers that arise because of services being planned and designed without meaningful input from everyone in the service area preclude certain people from easily or fully using the transportation network. Outlining the then-current transportation landscape in the United States, Sanchez et al. (2003) described persistent challenges and barriers to participation and access that result from historical decisions. For example, many areas of the country rely on personal vehicles due to historical emphasis on highways over transit. As a result of these types of imbalanced investments and the associated residential segregation and land-use disparities (e.g., low-skilled jobs located far away from low-cost housing), underserved populations often experience restricted access to opportunity (both economic and social), education, and health. During decision-making processes, additional barriers are introduced due to limited information availability or language barriers; those users with the time and resources to understand the options and the methods of influencing decisions are often the ones who benefit most from the outcomes (Sanchez et al. 2003). In other words, "Inequity experienced by some people is accompanied by unfair privilege for others who are not burdened by the same disadvantage and who benefit from a relative position of greater power than oppressed communities" (Equiticity 2019).

Table A-1. Definitions—Representation, implicit bias, and structural inequity.

Term	Definition
Representation	"Method or process of enabling the citizenry, or some of them, to participate in the shaping of legislation and governmental policy through deputies chosen by them" (Encyclopaedia Britannica 2012).
Implicit Bias	"Process of associating stereotypes or attitudes towards categories of people without conscious awareness" (Osta and Vasquez 2019).
Structural Inequity	"How policies and practices embedded in systems such as social welfare, economic, justice and health care operate to produce inequitable distribution" of social goods (Browne et al. 2012).

Lugo (2018) explained that the history of race and class division in America has become habitual and self-reinforcing—this "human infrastructure of racism" established a habitual process of separation and division (with enforcement via "reprimands big and little sent down the line to those who deviated") that supports today's subconscious or implicitly biased decision-making and continued segregation in our communities. The imbalance in decision-making around transportation means that "access to a car, the ability to safely ride a bike, or the use of public transportation are all impacted by systems of power and inequality" (Baltus 2019). Fullilove (2017) described the American experience as "an ecology of inequality" in which our governance structures rely on the inequality that was first leveraged to establish and facilitate the slave trade and slavery in America. Despite hard-earned civil rights legislation, centuries of racism and resistance have resulted in a "condition of being black in the Americas that is predicated on struggle" (McKittrick 2011). Hamilton and Strickland (2020) explained that this extreme level of inequality is tied to "the use of strategic racism to consolidate economic and political power for the few at the expense of everyone else." Such inequality results in uneven accumulation of network capital, which Elliott and Urry described as a combination of capacities to be mobile, including appropriate documents, money, and qualifications; access to networks at a distance; physical capacities for movement; location-free information and contact points; access to communication devices and secure meeting places; access to vehicles and infrastructures; and time and other resources for coordination (as cited in Sheller 2018). The result is that those within the elite classes "accumulate network capital, while relegating others to situations of slow, encumbered, or vulnerable mobility" (Sheller 2018).

Even public transit, often promoted as a solution to transportation inequity, is "always pursued for distinct purposes, and for the benefit of some urban dwellers and to the detriment of others" (Enright 2019). According to Enright (2019), this fact highlights the challenges of representation, trying to determine "who belongs in the city, who is allowed to participate fully in urban activities, who decides how space will be planned and produced, and who gains from urban transformation," factors that are "a complex bundle of often invisible political relations—of for example, poverty, racism, ecology, and citizenship—that condense power dynamics."

Use of New Mobility Options by Underserved Groups

An aspirational benefit of new mobility services is that they may provide transportation for those who are underserved and disadvantaged due to not being able to drive as a result of disability, age, or lack of access to a car (Zmud and Reed 2019). For example, new mobility services can provide better access to employment. In low-density cities with sparse public transport services, a private car can be a critical factor in finding (and maintaining) paid employment. A study by Junken (2015) examined public transit data from 43 U.S. metropolitan regions (Levinson 2013; Owen and Levinson 2014) to compare the accessibility of work by car compared to transit. For Los Angeles, 92% of jobs required a public transit commute of greater than 1 hour because of multiple transfers, whereas only 7% of jobs required a car commute of greater than 1 hour; other U.S. urban regions have a similar ratio. New mobility services may also provide new opportunities for employment, such as becoming a TNC driver. In terms of healthcare, improved mobility can enable citizens to attend medical appointments more readily, as noted in *TCRP Research Report 202* on dialysis transportation (Edrington et al. 2018). More specifically, people might be less likely to miss school/work due to more severe conditions, and it might be possible to treat persons with chronic conditions as an outpatient rather than via inpatient care, thus greatly reducing the overall cost of treatment. Improved mobility might also mitigate the negative consequences of food deserts, which contribute to social and spatial disparities in health outcomes (Beaulac et al. 2009). Although new mobility options have the potential to increase access to opportunities for underserved populations, they may also jeopardize access

by weakening the viability of existing options, such as public transit (Zmud 2018). Therefore, deploying accessible new mobility fleets in conjunction with the expansion of public transit and active transit will help safeguard low-cost and accessible transportation options.

Private transportation options, such as mobility on demand (MOD) or employer shuttles, can expand transportation options for all, "sometimes as an amenity and sometimes as a necessity" (Valenzuela et al. 2005). According to Feigon et al. (2018), private transportation options such as MOD may be the only viable options in certain areas or for certain trips because a public option does not exist. Provision of private options offers underserved communities the chance to be better connected to their regions but also presents potential barriers to access associated with the nature of private business (e.g., cost, span of service, technology or banking requirements, or preferential service provision). Cervero (2017) acknowledged the lack of "inclusive service mandate[s]" for private transportation providers but highlighted the fact that services like jitneys (route-based, flexibly scheduled, low-cost private bus or car services) have "improved access for immigrant and geographically isolated communities for decades."

Although the user base of new mobility services is still growing, at present, these services serve a small fraction of the U.S. population. For example, as of fall 2018, 36% of Americans had used TNC apps (Jiang 2019), but only 19% of rural residents, 24% of people aged 50+, and 24% of persons in households with incomes less than $30,000 had used such services. TNC users are overwhelmingly urban, young, and affluent adults. Even as bikesharing membership continues to grow, carsharing membership numbers appear to have flattened. Both services are still mostly confined to dense urban areas and represent a small percentage of regional travel (Zmud 2018). Despite potentially providing disadvantaged communities with additional service offerings and the fact that many new service pilots were launched specifically to broaden access to shared systems, these new mobility services have failed to gain traction among older, low-income, and non-White users (Shaheen et al. 2018). Shaheen et al. (2017) discovered that shared mobility users do not reflect their communities well. According to the authors, in addition to the limited representation of people of color among shared mobility users, typical users share the following characteristics:

- Are young.
- Have a high income.
- Have a high education level.
- Are tech-savvy.
- Have access to the full banking system.

Bikesharing and E-Scooter Sharing

Bikeshare systems have the potential to provide additional access to underserved populations because they offer low-cost services and are available around the clock; however, research shows that outcomes do not match expectations. In 2012, statistics about users of bikeshare systems in Minneapolis; Montreal; Denver; and Washington, DC, indicated that "bike share users in these systems are White (79%), highly educated (85% holding a bachelor's degree or higher) and middle-to-upper income (72% earn an annual income of $50,000 or above)" (Goodman and Handy 2015). Similarly, Ursaki and Aultman-Hall (2015) determined that bikesharing was less accessible to disadvantaged groups. *Special Report 319: Between Public and Private Mobility: Examining the Rise of Technology-Enabled Transportation Services* showed that bikesharing attracted users who were "disproportionately" moderate- to high-income earners (Committee for Review of Innovative Urban Mobility Services 2016). A 2016 report noted that, in four of eight bikeshare systems in the United States, White users with college education and higher incomes were overrepresented among users (Ursaki and Aultman-Hall 2015)—findings supported

by a survey of bikeshare users conducted by Gavin et al. (2015), which found that respondents were majority White, young, male, higher income, and better educated. In 2015, San Francisco bikeshare members had the following characteristics: 70% were male, 87% held a college degree, 75% were White, 80% had an annual salary of $75,000 or above, and almost 30% reported an annual salary of over $200,000 (Shaheen et al. 2017). According to Populus (2018), in a study of bikeshare use, women had not embraced traditional bikeshare options (docked systems) at the same rate as men (12% of women had used these services compared to 21% of men); however, in early analyses of micromobility options (focused on electric scooters), 3.2% of women had tried the service compared to 4.4% of men. This finding may indicate that micromobility options have a narrower gender gap among users than docked bikeshare systems (Populus 2018). Rayle et al. (2016) noted that there may be a correlation between smaller household sizes and increased demand for micromobility. A study of bikeshare equity in Santiago, Chile, found that 20% of trips were made by users under 15 or over 65 years old (Tiznado-Aitken et al. 2021).

When assessing a reduced-fare program for residents of New York City's Housing Authority properties, Greenberg (2018) found that fewer than 2% of annual bikeshare members were housing authority residents (despite the fact that the program was developed specifically for this community). One exception to these research findings comes from Baltimore, Maryland, in which Chavis et al. (2018) discovered that bikeshare users in that city have lower incomes and less education and are more likely to be people of color, Hispanic, or female. In a survey of people with disabilities in San Francisco, only 7% reported using bikeshare services due to barriers to inaccessible vehicles and safety concerns (Ruvolo 2021). Dill and McNeil (2021) found that even when bikeshare vehicles are nearby, populations that include people of color, low-income individuals, women, and older adults use the mode less and are less likely to be members of the service.

A case study analyzing bikeshare data in Chicago found that although annual subscription rates were lower in low-income communities, trips from these neighborhoods on bikeshare were longer trip distances, subsequently causing the average trip expenditure to be higher for these users (Qian and Jaller 2020) and possibly indicating a mismatch between land uses. Research on usage of shared mobility pilots in Los Angeles found that each micromobility pilot with programs designed to include low-income riders had different levels of success in attracting these users; more successful programs had more dynamic outreach and input in communities with user groups. Overall, 6% of the total trips taken between the three programs were completed by low-income users (McKinney 2020).

Carsharing

Carsharing presents the opportunity for users to travel according to their schedule, use their preferred route, make multiple stops, travel with family and friends, and carry baggage easily—features that may be most sought after by individuals who do not otherwise have access to automobiles. Despite the potential for high demand among underserved populations, research on carshare programs shows a similar pattern to bikeshare programs—carshare users are predominately high-income, highly educated, young, and White. Furthermore, some researchers have found a correlation between income level and propensity to use carshare, showing that lower income is predictive of lower carshare use (Committee for Review of Innovative Urban Mobility Services 2016; Dias et al. 2017); sometimes, this result can be due to the lack of available services in low-income neighborhoods (Martin et al. 2020). Dias et al. (2017) also determined that the effect of low income on the use of carshare (and ridesourcing) is more pronounced when a family has children. In separate studies of New York City and Oakland, respectively, Shellooe (2013) and Brown et al. (2017) learned that carsharing locations were more prevalent in areas with higher incomes and, in the case of New York City, higher education levels. Despite

multiple studies showing that carsharing is more common among people with higher incomes, Dill et al. (2014) found that Portland's carshare system was most used by adults 35 and older with lower incomes. Mitra (2021) analyzed data from the 2012 California Household Travel Survey and found that lower-income households are less likely to utilize carsharing (compared to other households). Focus groups in East Oakland found that many participants (particularly those who were Spanish-speaking) had not previously heard about available carsharing services in the area and were interested in using them for one-way errand trips (Pan and Shaheen 2021).

Thumm (2017) noted that carsharing is inherently restricted to those users who possess or can legally acquire a driver's license—thereby limiting this option to users who are old enough to drive, are able to accept the liability associated with carsharing, and have access to credit; are able to obtain a social security number; and do not have a criminal record that precludes them from having a license. Scooter-share programs can also require users to hold a driver's license as part of their rules, which can disproportionally affect users of different ethnic backgrounds based on unequal application of the law; for example, racially discriminatory policing on African Americans can result in suspension of driver licenses and limit access to shared mobility options as a side effect (Patterson 2020).

Ridesourcing and Microtransit

Research on ridesourcing users shows more diversity among users than what is seen in research on bikesharing and carsharing; however, much of the user base consists of younger, wealthier, and higher-educated people. A key difference among the users of ridesourcing and other new mobility options is that people of color are better represented. According to a survey conducted by Morning Consult in 2015, "Minorities may use ridesourcing in higher proportions, with 25% of Caucasian respondents reporting having used ridesourcing apps compared to 49% of Hispanics and 41% of African Americans" (Shaheen et al. 2017). The authors noted that the high level of use by people of color could be tied to greater availability of ridesourcing in urban areas and lower automobile ownership rates among this group (Shaheen et al. 2017). Looking at the rate of ridesourcing adoption by different communities, Clewlow and Mishra (2017) found that the highest rate of adoption was among Black users, followed by Asian and Hispanic users, respectively, with White users having the lowest rate of adoption.

Despite the increased participation in ridesourcing by people of color (compared to bikesharing and carsharing) shown by some research findings, the other user characteristics—wealth, age, and education—are unrepresentative of the communities where service is offered. According to Shaheen et al. (2017), a 2016 poll conducted by the Pew Institute found that ridesourcing users had college educations and household income levels above the national median, were under 45 years old, and lived in urban and suburban areas. Rayle et al. (2016) documented findings like the Pew results when assessing ridesourcing users in San Francisco. Though the survey did not ask respondents about their race or ethnicity, Rayle et al. concluded the following: ridesourcing users were generally younger, owned fewer vehicles, and were better educated than the general public; this group often traveled with others; and the group of respondents did not include adequate representation from households making less than $30,000 per year. Focus groups with residents in East Oakland found that TNCs were used mainly for social or recreational trips as a backup mobility option when their personal vehicle broke down; TNCs were not used more frequently because of the cost of trips and rides being canceled by drivers (Pan and Shaheen 2021).

Of note, microtransit is a form of ridesourcing; however, most literature does not differentiate these services from traditional ridesourcing options available from TNCs. An evaluation analysis of a microtransit project in East Gainesville, Florida, noted that agency-owned microtransit

services (wherein the public agency owns the vehicle fleet) can help ensure better accessibility for historically underserved populations through increased provision of wheelchair-accessible vehicles (WAVs) and service-zoning in underserved areas (Mohebbi et al. 2021). Microtransit pilots in Los Angeles and Washington State, which were partially aimed at providing increased transit accessibility to historically underserved populations, revealed instead that characteristics of riders were not significantly different from standard transit users (Lewis and Puentes 2021).

AV Technologies

Shared versus Personal AVs

Recent literature and policies largely assume a shared or Mobility as a Service (MaaS) model for AVs rather than a private use model. SAVs and associated shared model policies can have more equitable outcomes by decreasing the cost of operating, maintaining, and using SAVs, which benefits lower-income populations as well as rural populations who may have higher transportation cost burdens.

Developers currently testing and deploying shared AVs, such as the Lyft–GM partnership as well as Uber in Pittsburgh, Tempe, and San Francisco, provide opportunities for consumers to test AV services to relieve concerns about the new technology (Lewis et al. 2017). This opportunity can provide more equitable outcomes by providing experience to the user—and feedback to the developer—for populations who are distrustful of AV technology or technology in general.

AV market penetration is dependent on the overall costs associated with AV design and deployment. If SAVs can decrease this cost, they will be more competitive and produce more equitable transportation options compared to personal or asynchronous AVs (Ongel et al. 2019). However, SAV convenience could also increase demand for vehicles and result in greater vehicle miles traveled (VMT). To mitigate these effects, early policy intervention is necessary (Paddeu et al. 2020).

On Demand versus Microtransit AVs/SAVs

Although much of the current literature highlights the predicted risks and benefits of on-demand AVs, microtransit AVs present additional travel opportunities to connect underserved populations. Autonomous microtransit (AMT) vehicles vary in size and service, are driverless, and can be used to supplement larger transportation systems. For example, the company EcoPRT successfully piloted an AMT program that transports two passengers at slow speeds (10–20 mph) on shared-use paths at a low cost. The AMT program was used at North Carolina State University in conjunction with the local bus system to increase access and reduce parking [North Carolina Department of Transportation (DOT) 2019].

A study by Ongel et al. (2019) analyzed the cost of electric AMT vehicles compared to the cost of traditional single-occupancy vehicles (SOVs) and public buses. The study found that although the initial cost of electric AMT vehicles was higher than traditional SOVs, the *total* cost of ownership (including operation and maintenance) was reduced by 75% compared to internal-combustion-powered SOVs and buses. The reduction in cost could be attributed to the electrification of the AMT vehicle's powertrain (including the engine, transmission, and driveshaft). Furthermore, the authors noted that van and mini-bus-sized AMT vehicles with 10–30 passengers can be used for fixed or on-demand service and operate alongside traditional public transit systems (Ongel et al. 2019). To be used in fixed-route public transportation services in the United States, the vehicles have to be ADA-accessible. ADA-accessible minibuses can serve transportation-disadvantaged populations, particularly low-income and rural populations, at a lower price for riders due to the shared nature of the service and the lower operational costs.

Potential Adoption of AV Technologies

It is difficult to measure consumer perceptions of AVs/SAVs since the majority of consumers lack sufficient information on AV/SAV technology. As a result, most studies focus on early adopters of other new vehicle technologies (Berliner et al. 2019). A 2019 study of early plug-in electric vehicle adopters in 36 U.S. states by Hardman et al. (2019) indicated that early private AV adopters will likely be wealthier and have positive perceptions of safety, comfort, technology, and price when it comes to AVs, along with considerable knowledge about the technology.

Hardman et al. (2019) also identified a socioeconomic study cluster grouping called the "laggards," the members of which tend to be distrustful and resistant to technology and have negative perceptions of safety and cost. It could be inferred that low-income populations who experience AV cost barriers, older adults who are distrustful of AV technology, and older adults and populations with disabilities who are concerned about AV safety might all fall within this category. Kassens-Noor et al. (2020) found from survey efforts in Michigan that respondents who were older adults, identified as female, or had mobility disabilities were less likely to be willing to ride AVs.

An additional study by Berliner et al. (2019) focusing on early electric vehicle adopters in California found that younger, wealthier men were the participants most interested in purchasing a private AV and were therefore likely early adopters of AVs. The study participants had an average household income of $185,000, and 48% held master's, doctorate, or professional degrees. Also, irrespective of demographics, participants who perceived AVs to be safer than non-AVs were more likely to purchase a fully automated vehicle. From these findings, it can be inferred that lower-income populations and older adults are not as likely to purchase a fully automated vehicle, which will diminish travel opportunities and widen the travel equity gap. However, greater integration of transportation-disadvantaged populations, such as low-income people, people with disabilities, and older adults, into early adoption studies will allow researchers to better understand the barriers to access facing these populations as well as provide an opportunity for these groups to learn more about AV/SAV deployment and potential increases in accessibility as a result.

An onboard intercept survey of bus riders in Michigan found that safety was a main concern for riders with disabilities not willing to ride in AV buses; these perceived safety concerns included risk of accidents, mechanical failures, and hacking or malfunction of the vehicle computer systems. A few respondents also indicated the need for human assistance either for their disability needs or in case an emergency occurs as reasons not to ride in an AV (Kassens-Noor et al. 2021).

A study by AARP on older adults and new mobility noted that shared mobility companies and developers of AVs have focused on the needs of older adults that are similar to the overall use case population, including with respect to mobility, cognitive and physical capabilities, income, and technology fluency. Although older adults have begun using ridehailing services as an alternative mobility option to driving themselves, not considering the specific needs of other types of individuals may likely result in some populations being excluded from future new mobility developments at the onset. Exclusion of specific needs from the development of AVs will continue to leave older adults reliant on unreliable mobility options even while they represent a demand market for AVs (Fraade-Blanar et al. 2021). Wu et al. (2021) stated that policymakers must require technology companies to include historically underserved populations during the transitional period of AV development, adjust technology development to be free of biases, and test AVs with different users from different socioeconomic backgrounds.

Stantec and Applied Research Associates (2020) highlighted the potential of AVs in both urban and rural areas to enhance mobility and connectivity for transportation-disadvantaged

groups, including older adults, youth under 16 years old, people with disabilities, and people who cannot (or choose not to) drive. This benefit was echoed by Paddeu et al. (2020), who noted that SAVs can improve independence and decrease isolation for older adults, people with disabilities, and people with acute health conditions. AVs/SAVs have the additional benefit of providing first- and last-mile (FLM) connectivity, particularly for people with ambulatory disabilities and older adults who may be otherwise mobility-limited.

A study by Faber and van Lierop (2020) of older adults in the Netherlands found that participants were interested in using SAVs daily to improve mobility and accessibility. Older adults preferred the increased flexibility of on-demand booking and using SAVs for FLM services to alternate modes. Additionally, participants cited the benefits of traveling with friends for increased socialization; access to essential services, shopping, and social/leisure activities; and increased independence and connection with the community.

Factors Preventing Access and Use

Barriers to access and use are associated with various, often overlapping, factors. Peterson et al. (2019) outlined the diverse and interrelated nature of the barriers experienced by underserved communities (and the required solutions), noting that

> . . . low-income and transportation-disadvantaged populations face several barriers, and equitable solutions are equally multifaceted, ranging from where a service is located, when it operates and its travel time, to affordability and financial access, physical access, and any number of social and cultural influences.

Freund et al. (2020) created a framework that describes the factors for older adults' use of rideshare services, which considers biological and social traits, physical traits, special needs, and personal behaviors or preferences. The framework is organized as a hierarchy for each broader category of needs, beginning with individual needs and then working up through interpersonal, organizational, community, and public policy/marketplace needs.

Fraade-Blanar et al. (2021) researched issues in new mobility options for older adults and developed a framework to organize factors impacting use of these services. The framework for older adult mobility factors is organized by individual, organizational, and societal levels, each of the included factors for using mobility services. The framework is organized as follows:

- Individual Level.
  - Demand-Side Factors.
    - Smartphone Access.
    - Smartphone Use.
    - Access to Online Payment.
    - Affordability of Services.
    - Barriers of Trust and Attitude Toward Technology.
    - Physical Barriers.
    - Language Barriers.
    - Cognitive Barriers.
  - Safety Factors (Individual).
    - Non-Crash-Related Health Factors.
    - Personal Security Concerns.
- Organizational Level.
  - Safety Factors (Organizational).
    - Crash Prevention.
    - Vehicle Occupant or Pedestrian Safety.

  - Supply-Side Access Factors.
    - Accommodation of Goods or Aids.
    - Travel Options Fit with User Needs.
    - Travel Options Fit with Environmental Conditions.
    - Availability of Transportation Services in Area.
    - Consistent Transportation Service Availability.
    - Bias in Availability.
- Societal Level.
  - Land Use and Transportation Planning Factors.
    - Curb and Sidewalk Management Policy.
    - Street Cross-Section Design.
  - Transportation System Factors.
    - Availability of Public Transportation Options.
    - Availability of Last-Mile Options.
  - Secondary Response Factors.
    - Other Impacts of New Mobility/AVs on Transportation System.

Shaheen et al. (2017), working to categorize the barriers to transportation experiences by underserved communities, developed the STEPS to Transportation Equity Framework—**s**patial, **t**emporal, **e**conomic, **p**hysiological, and **s**ocial barriers. To demonstrate how the STEPS concept could be used to assess barriers to shared mobility and begin to implement solutions, Peterson et al. (2019) outlined barriers experienced by people with low incomes. Using this approach as a model, the following sections document findings from the literature relevant to each of the STEPS component factors.

Spatial Barriers

Spatial barriers, such as density and land use, influence new mobility options (Howland et al. 2017). For example, according to Shaheen et al. (2017), low-density and low-income communities may be less likely to provide a market of users that will help private shared mobility services recover their costs or make profits, which can result in less service in these areas. Cohen and Cabansagan (2017) noted that to seek profits and growth, private-sector carshare and electric vehicle charging companies target locations where the immediate user base has higher incomes and is more familiar with the technologies instead of neighborhoods where income is lower. New mobility services tend to start in places with levels of density (people and uses) high enough to achieve ridership goals that can generate a return on investments; they often avoid rural, less dense, or low-income geographies (Beale et al. 2022). Localized or geographic restrictions on micromobility service areas are a common regulatory approach that can limit benefits for historically underserved areas if these neighborhoods do not have specific vehicle provisions and rebalancing requirements (Samsonova 2021).

Shared mobility options offer the potential for improved territorial accessibility through a more equitable distribution of vehicles and drivers, but without planning, policy, or oversight, these service options can instead become geographically concentrated (International Transport Forum 2017). For example, carsharing vehicles might increase low-income individuals' ability to use a car for trips as needed because vehicles can be located anywhere such vehicles can be legally parked between trips (Committee for Review of Innovative Urban Mobility Services 2016; Dill et al. 2015). Additionally, shared mobility services available in underserved communities may not be as available in practice due to bias from vehicle provision or routing structures. An analysis of ridehailing data in Chicago found that pricing algorithms in the service software determined higher fare prices in neighborhoods with larger non-White populations and higher poverty levels. This effect was not due to surge pricing strategies but rather to a lower supply of

drivers in these neighborhoods, which effectively increased the cost for users wanting to take trips (Pandey and Caliskan 2021). This challenge of driver/vehicle availability in underserved areas can exacerbate barriers to transportation for low-income populations without access to a vehicle in shelters or temporary assistance facilities that are located away from the most desirable service areas (Robinson et al. 2021).

Because the service relies on fixed stations, traditional docked bikeshare systems are often associated with geographic availability challenges (Populus 2018). A study by Hosford and Winters (2018) noted that in Canada, "advantaged areas have better access to bicycle share infrastructure in Vancouver, Toronto, Ottawa, Gatineau, and Montréal," while "disadvantaged areas have better access in Hamilton." Similarly, Kodransky and Lewenstein (2014) determined that fewer stations in lower-income neighborhoods limit access to shared mobility for underserved communities. This pattern of development is enforced by business strategies that focus on locating stations in "attractive, multi-use neighborhoods and commercial corridors with vibrant economies and public spaces, areas where decades of social and financial pressure have minimized the presence of LIM [low-income and/or minority] residents" (Goodman and Handy 2015). Some bikeshare systems acknowledge the need to place stations in areas where they can be used by underserved communities, but these efforts are frequently hampered by limited funding (Ursaki and Aultman-Hall 2015), thus forcing the systems to target areas that have higher densities and higher incomes to garner higher rates of revenue generation from user fees. Whalen (2022) analyzed bikeshare docking stations' relationship to gentrification using data from Chicago. The study found that low-income neighborhoods located closer to stations in 2014 experienced an increase in median household incomes 5 years later. Although other factors might be at play, this finding raises concerns about the potential for bikeshare stations and infrastructure to inadvertently contribute to the displacement of the very populations they aim to serve.

The spatial availability challenges associated with new mobility are influenced by public resources and planning decisions. McNeil et al. (2019) learned that smaller bikeshare systems have experienced limitations associated with staff availability and funding that reduced the size of the system and its resources. Emphasizing the impact of funding on bikeshare systems, one expert interviewed by the authors divulged that placing the bikeshare service in areas that can generate revenue is the only way some jurisdictions (e.g., cities) are willing to implement a system.

Carsharing services designed specifically to facilitate access to bus systems and bridge FLM gaps are often limited or completely unavailable in lower-income neighborhoods (Thumm 2017). Additionally, low-income areas within service markets tend to have difficulty getting trip requests fulfilled by drivers or having micromobility vehicles staged nearby. Concentrations of dockless micromobility in already highly dense areas can create social consequences through an effect of "splintering urbanism" by widening the gap between citizens with lots of transportation options and citizens without in historically underserved areas (Chen et al. 2020).

AVs/SAVs may introduce specific challenges depending on the operational environment. Although this technology can offer city dwellers increased travel accessibility, if left unregulated, private AV companies can potentially focus efforts on, and profit from, wealthier urban service areas, thereby increasing mobility disparities that have already been observed with current shared mobility modes (Wu et al. 2021). Stantec and Applied Research Associates (2020) noted the resulting possibility that AVs could reduce mobility options and services for disadvantaged populations, particularly low-income urban populations and low-density rural populations.

An additional concern cited by Emory et al. (2022) is the indirect impact on access that AVs can have on rural and low-income populations. Because low-income populations have low rates of car ownership and urban low-income populations are often transit-dependent,

a fear exists that AV deployment will decrease affordable and accessible travel options, such as public transit. Additionally, rural populations already have low access to multimodal transportation, and people without vehicles or the ability to drive are dependent on others for mobility, further limiting transportation options for these populations. Currently, the limited supply of shared mobility options away from the urban core can result in longer trip durations and therefore more expensive travel costs for people living in rural areas (Martin et al. 2020).

To prevent the minimization of low-cost and accessible transportation options for low-income and rural populations, scholars have suggested that AV/SAV deployment should occur simultaneously with the expansion of public transit and active transportation options in both urban and rural settings (Emory et al. 2022).

Temporal Barriers

Time is a component of travel decisions and convenience regardless of mode. Traditional transportation options often involve certain types of time-based compromise (e.g., wait times, pre-planning and scheduling, congestion-based delays, or lack of service options) that many new mobility options seek to overcome (Shaheen et al. 2017). However, while new mobility options are temporally flexible, real-world experience shows that time may still be a barrier for some users of new mobility.

Ridesourcing, often described as a service that is available on demand 24 hours a day, reacts to market forces (e.g., densities of people and jobs) in a way that creates wait times that reflect rush-hour commutes or other high-demand events (e.g., concerts) and might reduce service availability for people traveling outside of these peaks due to the drivers' ability to focus on high-demand and higher-paying peak periods (Shaheen et al. 2018).

According to Zalewski et al. (2019), the lack of non-SOV transportation options for late-shift workers results in a disproportionate number of late-shift workers experiencing transportation cost burdens (approximately 30% of late-shift workers' pre-tax earnings are spent on car ownership). Expanding on the potential for increased negative impacts associated with a lack of affordable late-shift transportation options, the authors noted that the late shift is "only growing in importance . . . sectors, such as healthcare, food services and hospitality/leisure, are expected to grow faster than overall employment over the next five to 10 years." Goodman and Handy (2015) found similar restrictions on late-shift transportation among bikeshare systems, noting that low-income and minority users are burdened by the fact that some systems limit the hours of operation to traditional 9-to-5 work shifts and/or use bicycles that prevent users from bringing their children or carrying baggage (e.g., groceries).

Traditionally, public transportation services have been designed to serve morning and evening commute trips; as such, the needs of other system users (e.g., off-peak commutes, mid-day errands, travel with children) have been neglected (Halais 2020). New mobility services are frequently considered as options to augment or replace transitional transit services; however, if these new options are developed under the same planning assumptions as traditional services, they may not provide benefits for all users of the transportation system. Halais (2020) outlined some of the current challenges imposed by existing service design that may continue in new mobility options if planners do not confront them:

- "Most transit systems aren't designed for women, who tend to run errands and care for children. . . . Public transportation is sexist."
- "Women around the world do more care and domestic work than men and their resulting mobility habits are hobbled by most transport systems. The demands of running errands and caring for children and other family members mean repeatedly getting on and off the bus, meaning paying more fare. . . . Transport systems are ill-suited to [women's] needs."

- "Transit schedules are mostly designed to accommodate 9-to-5 workers, resulting in longer wait times for anyone traveling outside peak hours. Many subway stations lack elevators to carry strollers from curb to platform."
- "In cities that don't have integrated transit services—or instances where the subway is run by one company and the bus by another—people who 'trip-chain' must pay a fare for each leg of the trip, inflating their transport costs."

Economic Barriers

New mobility options are only useful for currently underserved populations if the costs (direct and indirect) of the service are affordable. Due to high costs (of the required technology and the service itself) or reduced access to the banking system, some users have not been included in the technology-based mobility revolution (Kodransky and Lewenstein 2014; Shaheen et al. 2017).

Required Technology

New mobility services depend fundamentally on the use of internet connectivity, often through a smartphone, that allows for the exchange of important data between the user and the operator. This innovation significantly restricts access to such mobility services to individuals who have access to the necessary hardware (e.g., smartphone), the right data package, and the ability to download/operate mobile applications (Chen et al. 2020). Smartphone users in the United States represented just less than 70% of the population in 2017 (Statista 2018)—meaning that mobility services that depend fundamentally on a smartphone were not accessible to more than 30% of the U.S. population. Table A-2 presents additional findings related to the limitations experienced by users without the required technology.

With the introduction of AV technologies in the MOD space, trust and user perspective may add to other technology barriers. A study conducted by Man et al. (2020) that evaluated AV acceptance in Hong Kong found that for Level 3 AVs, trust was the most significant factor impacting attitudes toward the technology. Both the perception of safety and the technological

Table A-2. Technology barriers.

Finding	Source
"The lack of smartphone data access and credit/debit cards may be a barrier for disabled, low-income, and older adult users."	Shaheen et al. 2017
"The participants also identified that affordability and technological barriers besides a lack of familiarity and consequence misconception as the potential causes of the lack of awareness or willingness to use car-sharing service."	Hyun and Cronley 2019
"Mobility consumers are becoming increasingly dependent on smartphone hardware and applications, but the data packages required are often expensive." As such, low rates of smartphone ownership result in a barrier to access, or "the 'digital divide.'"	Shaheen and Cohen 2018
"On-demand services are typically reserved through a mobile app. Communication between the phone and the service provider is necessary to hail the service. Rural communities may have cellphone coverage gaps, thereby potentially limiting access to on-demand services. Accessing services from a landline limit where travelers can book and pay for different modes. Additionally, travelers with lower incomes may only have pay-as-you-go smartphone data plans rather than data subscriptions. The data plans may limit access particularly when the plan value needs to be replenished and the traveler does not have access to retail outlets that take cash."	Chang et al. 2019
"Another spatial barrier is lack of access to mobile service and high-speed data which may be more limited in low-income and rural areas. Slower internet speeds can create challenges for shared mobility providers when locating users and processing real-time transactions. This can deter operators from locating in areas without existing high-quality mobile internet infrastructure."	Martin et al. 2020

factors (compatibility and system quality) impacted participants' level of trust. For older adults, riders with disabilities, and non-English speaking riders, trust in technology and the perceived safety of AVs will be influential factors in AV acceptance and should be considered in AV design and educational outreach.

Faber and van Lierop's (2020) study of older adult perceptions of AVs/SAVs found that older adults are particularly concerned about potential AV breakdowns and how AVs will anticipate complex traffic scenarios. The authors argued that trust in AV technology can be fostered with an AV ambassador—a rider/community member/pilot participant who encourages the use of AVs/SAVs by educating others about AV safety and assuaging perceptions of feeling unsafe. Persons with visual disabilities may also have issues with identifying their matched AV from information in the smartphone app. For example, current TNCs often use license plate numbers, vehicle makes and model names, and images to help identify the vehicle; these users can sometimes overcome this barrier by contacting the driver, but the issues will persist with AVs if not addressed. TNC users with visual disabilities can find communicating with the driver to be the most challenging aspect of the travel mode (Brewer and Ellison 2020).

Stantec and Applied Research Associates (2020) cited the issue of trust in AV/SAV technology and lack of awareness of AV services as a potential barrier for non-English speaking populations. To counteract this barrier, educational efforts, as well as in-app AV information, should be included in multiple languages for non-English speaking riders, and alternatives to apps may be considered if riders have a lack of trust or understanding of technology in general.

Service Costs

New mobility services may require additional investment from users compared to traditional options because they (a) require the users to invest in new technology to access the service, and (b) do not receive the same levels of public subsidy as traditional services. Shared mobility may also provide a low-cost solution for bridging existing transportation gaps by providing FLM connection to transit or offering a stand-alone service option in areas without existing public transit. Shared modes can be deployed in underserved areas in less time at a lower cost than traditional transportation projects due to the speed of private-sector investment and operational setup (Shaheen et al. 2017). However, some shared mobility systems are owned by firms that rely on venture capital funds, which increases pressure for the service to be profitable above other considerations and inflexibility with making adjustments to pricing structures (Dill and McNeil 2021; Yaffe 2020). Additionally, when a service withdraws from a market (due to profitability or other concerns), local residents may become confused about the mobility options available for use (Dill and McNeil 2021).

Families with children experience challenges related to overall travel costs when using new mobility options. Dias et al. (2017) determined that the trips and trip-chains required by families with children are so complex (requiring multiple stops and/or longer distances) that use of TNCs can become cost-prohibitive. Affordability of accessible transportation options on TNCs is a key concern for persons with disabilities who wish to use the service (Ruvolo 2021). During the COVID-19 pandemic, TNCs were used by some populations dependent on public transit who were faced with reduced service schedules, which created financial hardship for low-income populations as well as some persons with disabilities and older adults taking more trips on a higher-cost transportation option (Brown and Williams 2021).

Bikeshare users also cite cost as a barrier to using the system. The bikeshare costs associated with diminished access include membership, potential liability, and fares (Howland et al. 2017; McNeil et al. 2017). McNeil et al. (2017) learned that cost concerns are linked to low-income status and race. They revealed that in their study,

> . . . costs of membership and concerns about liability for the bicycle were a big barrier for about half of lower-income people of color (48% and 52%, respectively), compared to 33% and 31% of higher income respondents of color and only 18% and 10% of higher-income white respondents. These figures reveal that concerns about price and over being charged for a problem with the bike are related to both income . . . and race.

According to Goodman and Handy (2015), the risk of incurring additional fees associated with extended trips and the potential for these fees to be unpredictable or beyond the users' control (e.g., if a bikeshare station is full and a user is forced to travel longer than the allotted time to dock elsewhere) keeps some people from using bikeshare. The authors also learned that a lack of parity between bikeshare fares and transit fares (e.g., low-income programs for transit that do not work on bikeshare) diminishes interest in the service among some groups. Evaluating the relationship between household location and transportation costs, Tibbits-Nutt (2019) found that households with lower incomes are forced to dedicate a greater amount of their income to transportation due to increased travel distances between home and work locations.

Reviewing challenges related to subsidies, multiple authors have determined that existing subsidy strategies either do not improve equity or do not address equity. According to Cohen and Cabansagan (2017), subsidies for TNCs have the potential to improve service efficiency and access for users of the service, but the planning for these subsidies often does not include an assessment of potential equity impacts, such as the transit service cuts, they may help justify. Cohen and Cabansagan noted that because the new services are more costly to provide, monthly costs for riders could increase significantly even after subsidies due to the common practice of transferring costs to riders, and ADA-accessible service, such as complementary paratransit, is at risk if transit systems transition to a TNC subsidy model. Bikeshare and carshare subsidies also struggle to improve equity of service. According to Shaheen et al. (2018), as of 2016, 24% of the bikeshare systems in the United States were offering subsidized memberships for low-income users, and the carshare subsidies had the potential to expire after only 1 year.

When considering automation and barriers to access for transportation-disadvantaged populations, a common concern is that private AVs are economically costly or cost-prohibitive for some populations, including low-income people, older adults, and people with disabilities. Reviewing the barriers to widespread introduction of AVs, Fagnant and Kockelman (2015) found that the initial costs are likely to be unaffordable for the majority. For individuals who can afford these vehicles, the authors noted that "major social impacts" include reductions in crash rates, travel time, fuel consumption, and parking demand that translate into approximately $2,000 in savings per vehicle related to the time/fuel/parking benefits and another $2,000 in savings associated with reduced crash costs. However, according to Kaplan et al. (2017), between purchase costs approximately 35% higher than vehicles without automation and the service costs associated with AVs (e.g., network connections), annual vehicle costs might increase between $1,000 and $3,000. Further exacerbating financial challenges for low-income people, high demand for AVs among the general public "may lead to transit service cuts, not to mention the degradation and decline in safety of existing service and facilities. If transit-dependent riders are then forced to use [automated service options], they may have to pay more than their current fare, especially if the TNC surge price model is retained." Put simply, "Technology such as [automated vehicles] might be primarily for those who can afford it" (Koeppel 2017).

A report by Stantec and Applied Research Associates (2020) highlighted the potential for discrimination against people who are underbanked or unbanked and cannot use automatic bank withdrawal or credit card payment systems to pay for AV services. Faber and van Lierop (2020) noted that in addition to low-income populations, older adults with limited incomes and mobility choices may find AVs cost-prohibitive. Since paratransit is more expensive than fixed transit service, AV paratransit may create further barriers to access for older adults and riders

with disabilities. In response to the economically costly nature of AVs, Paddeu et al. (2020) suggested implementing government subsidies to pay for free rides for older adults and riders with disabilities.

Beyond the financial cost burdens, AVs threaten to impose quality-of-life costs in low-income neighborhoods. When exploring the potential for AVs in the Boston area, Kaplan et al. (2017) proposed that parking for AV fleets could be located in "inexpensive areas" of the region. People who cannot afford to access AVs may experience missed time-saving opportunities. Some authors forecast the potential for AVs to help users leverage their time more effectively by allowing other activities to take place during travel (Kockelman et al. 2016); however, this benefit will only be available to those who can afford the transportation option. The indirect societal costs of AVs/SAVs include the potential for increased urban sprawl by making travel more convenient. Emory et al. (2022) also noted the concern that governments could channel funds from transit and active transportation to AVs, decreasing low-cost and accessible transportation funding and negatively impacting urban, low-income populations that are often transit-dependent. The authors pointed to the additional fears of job loss, decreased incomes, and decreased job opportunities for TNCs or taxi operators, which are more likely to affect low-income populations and people of color. To counteract this barrier, the authors suggested transitioning drivers to roles as security attendants in AVs/SAVs and setting aside retraining and education funds for former drivers. Additionally, some persons with disabilities may feel safer using AVs/SAVs if an attendant with a valid driver's license and/or maintenance expertise is available to assist in the event of an incident or emergency (Feeley et al. 2020; Fraade-Blanar et al. 2021). However, this may not be a sufficient solution to cover the indirect costs of AV/SAV deployment, especially for low-income populations.

Despite the significant costs introduced by automation in the MOD market, these technologies are also expected to benefit society if implemented strategically. AVs, and especially SAVs, have the potential to create time cost savings and transportation cost reductions, particularly for low-income populations. A Stantec and Applied Research Associates (2020) report outlined the time savings potential of AV/SAV trips, including riders' ability to work, sleep, or relax, thereby increasing productivity and convenience. The deployment of convenient and efficient AVs/SAVs could lead to an increased number of routes, increased speed, and improved reliability.

Although cost barriers will likely not be reduced by personal AVs, Emory et al. (2022) pointed toward the reduction in individual AV costs by encouraging shared AV use, which can improve accessibility for low-income populations without increasing cost. To this end, SAVs have the potential to decrease the cost of transportation and reduce the disproportionate cost on U.S. households in which housing and transportation expenses exceed 45% of income (true for two-thirds of American households). This reduced cost burden can be attributed to cost reductions in fuel, insurance, and ultimately AV/SAV technology. Road user charges and additional usage-based fees can also be used to reduce costs for low-income populations and rural populations (if progressively tiered user charges are implemented).

For travelers who are transportation disadvantaged, AVs/SAVs have the potential to increase access to essential services (e.g., jobs, medical care, grocery stores), as well as increase employment opportunities by providing convenient and reliable trips for those with limited transportation options, especially in urban settings (Stantec and Applied Research Associates 2020). In particular, Emory et al. (2022) noted that travelers with disabilities and older adults can benefit from AVs due to lower baseline access to transportation than the general population (if travelers are unable to drive and/or take transit or TNCs). To this end, AVs/SAVs have the potential to help narrow the access gap for these populations.

Banking

A large proportion of the population is considered underbanked, meaning individuals may have a bank account but lack access to or choose not to access mainstream financial services. Consequently, a significant number of potential mobility users are deprived of adequate banking facilities, with younger, undereducated, unemployed, and elderly individuals most at risk. This situation creates a challenging societal inequity through poor access to new mobility services.

According to the 2021 Federal Deposit Insurance Corporation (FDIC) National Survey of Unbanked and Underbanked Households, 28.5% of households did not have a credit card (FDIC 2021). Moreover, 4.5% were unbanked, and 14.5% were underbanked, with much higher rates among marginalized communities. Unfortunately, a major barrier to accessing bikeshare services is not having access to a debit card or bank account. Bikeshare systems often require a credit or debit card to sign up for a membership or require cash payers to make payments at their office (McNeil et al. 2019). For low-income individuals, additional requirements to sign up with some micromobility systems may include government-issued photo IDs, proof of enrollment in assistance programs, and access to a computer to upload documents. These additional barriers could be relaxed/augmented to help potential users access the service (Frias-Martinez et al. 2021).

Credit card and banking requirements have consistently been shown to be a barrier to use of new mobility options in various research projects since 2014. According to this body of research, limited access to the banking system is often related to low-income status, low or nonexistent credit scores, or limited trust in the financial/governmental systems associated with banking—which may be potentially related to immigration status (Cohen and Cabansagan 2017; Committee for Review of Innovative Urban Mobility Services 2016; Goodman and Handy 2015; Kodransky and Lewenstein 2014; Shaheen and Cohen 2018).

Banking challenges extend to automated technology too. Stantec and Applied Research Associates (2020) pointed out that a lack of access to smartphones, credit cards, cell phone data, and the internet can make AV/SAV use challenging or impossible for low-income populations and/or populations who are underbanked or unbanked.

To address these barriers to economic accessibility, Emory et al. (2022) suggested that AV/SAV providers consider cash and subscription-based payment options for low-income populations and populations who are underbanked and unbanked. Digital accessibility can be improved and ensured through the use of the U.S. Department of Justice webpage accessibility checklist (https://www.ada.gov/access-technology/guidance.html). This checklist can be used for webpages and apps to determine the extent to which the content is accessible to most people with disabilities (auditory, visual, cognitive, and ambulatory).

Physiological Barriers

People with disabilities, older adults, and those unfamiliar with current technology may experience barriers to new mobility options related to physiological access—ranging from app usage limitations to a dearth of WAVs (Cohen and Cabansagan 2017; Shaheen et al. 2017). New mobility users who are blind have experienced challenges using ridesourcing services, including trip denials and abuse of their service animals (Wieczner 2015). Wheelchair users also experience ridesourcing trip denials because the drivers cannot carry the wheelchairs (Wieczner 2015), and considerations such as accessible vehicles and apps have not been adopted by all service providers (Shaheen and Cohen 2018). Older adults, whether or not they use a mobility device as an aid, can be less comfortable entering and exiting shared mobility vehicles (Fraade-Blanar et al. 2021). Families with children experience limitations related to the service's supplied vehicle options (Goodman and Handy 2015) or the need to bring child seats for use in ridesourcing or

carsharing services. TNCs typically provide WAVs through a third-party provider; in most cities, TNCs have been able to operate without providing equivalent accessible service, even though the U.S. Department of Justice has sided with disability rights organizations in some lawsuits (Ruvolo 2021).

Hyun and Cronley (2019) found that carsharing companies also lack considerations for accessible vehicles and services. The authors determined that carsharing operators

> . . . need to consider how accessible their cars are for individuals with physical disabilities . . . [and should] maintain fleets of cars that have wheelchair accessibility [as well as] advertise their accessibility features and educate transportation professionals so that people are aware of these features.

People with disabilities are commonly underserved by bikeshare systems. Ruvolo (2021) noted that persons with disabilities may be averse to trying micromobility due to the difficulty in imagining what types of accessible vehicles might be available if the bikeshare or scooter-share systems have not introduced many adaptive vehicles for persons to consider. MacArthur et al. (2020) found that 10 of 70 bikeshare systems responding to their survey had adaptive bikes in their systems. Challenges for operators to implement adaptive vehicles can include specialized parts and maintenance costs as well as an inability to spread vehicles throughout the system. Types of adaptive bicycles include tricycles/quadcycles (to improve balance), tandems (for people to ride together), handcycles (for people with limited/no lower-body movement), recumbent bicycles/tricycles (to allow for riding while seated), heavy-duty cruiser or cargo tricycles (for larger weights and carrying capacity), and electric-assisted vehicles (MacArthur et al. 2020; Yaffe 2020). According to Benedict et al. (2020), the City of Milwaukee, Wisconsin, launched a 6-month pilot of adaptive bicycles through its Bublr bikeshare program, including upright tricycles, handcycles, and two-person side-by-side bicycles, which could all be located and reserved through the system's app. Both BIKETOWN in Portland and MoGo in Detroit have adaptive bikeshare programs that include "tricycles, side-by-side tandems and hand-cycles, for people who are not able to ride a standard bike share bike" (McNeil et al. 2019). Additionally, Ford GoBike, in Oakland, California, conducted a 6-month pilot rental program to provide accessible bicycles for recreational use (Baldassari 2019).

People with disabilities and older adults thus face many difficult barriers to accessing the vehicles used to provide new mobility services, and the systems used to request and pay for services present similar barriers (Shaheen and Cohen 2018). Leistner and Steiner (2017), when researching a dynamic ridesharing program, found that a significant portion of the participants (about 15%) did not have smartphones when they enrolled in the service and that people who are not already familiar with the concept of dynamic ridesharing may be less likely to use the service. Chang et al. (2019) reported limited effort to design technology that can accommodate users with visual or cognitive disabilities. An evaluation of an AV demonstration in Phoenix found that users with visual disabilities thought the smartphone app for the service was less useful (than other users thought) and that accessibility of the app worsened over the pilot period (Stopher et al. 2021). Limited access due to technological advancements that preclude certain populations from traveling has the potential to result in health inequities and negative health outcomes—a risk that is particularly crucial for vulnerable populations, such as those with disabilities or older adults (Hanzlik and Schweninger 2019).

Wong et al. (2020) looked at perceptions of residents in California about using shared mobility services for transportation during emergency events (specifically wildfires) by conducting focus groups of identified underserved populations. Older adults did not have a positive perception of shared ride services due to concerns about the reliability of drivers and their availability to be in the area. Participants were also skeptical that ridehail drivers would willingly accept a ride to drive toward an emergency (i.e., into harm's way). Focus group participants with disabilities had negative perceptions of using TNCs in an evacuation event due to viewing

the services as not disability-friendly; issues included not having WAVs readily available, poor communication and lack of assistance from drivers, and past experiences with canceled rides. Low-income participants were likewise skeptical about the viability of TNCs for evacuation trips, concerned with surged pricing, and worried about the inability to pay without a bank account (Wong et al. 2020).

Although the lack of a driver in AVs cuts costs and removes human driver error, it can also make AV participation difficult for riders requiring assistance to enter and exit private AVs by themselves, particularly older adults and people with ambulatory and visual disabilities. Older adults who lose their licenses or are unable to drive have limited mobility, especially in car-dependent rural areas or transit-scarce urban areas. Faber and van Lierop (2020) noted that older adults may have limited active transportation capabilities and may be dissuaded from using public transit if transit is difficult to access physically, is unreliable, or has poor FLM connectivity, thereby limiting mobility options. Poor sidewalk conditions can be additionally prohibitive to navigate to and from transport vehicles for older adults and persons with visual or ambulatory disabilities (Ruvolo 2021). Mobility devices (e.g., walkers, canes, wheelchairs) can make boarding, alighting, and storing devices difficult (Faber and van Lierop 2020). These concerns are echoed when considering accessible AV design for older adults and riders with disabilities.

The National Association of City Transportation Officials (2019) also pointed to barriers outside the vehicle, including limited wheelchair-accessible infrastructure (e.g., level boarding platforms or ramps), which can create additional challenges for riders with ambulatory disabilities or older adults in both urban and rural areas. Such challenges can especially be a problem if AVs lack designated drop-off areas and if vehicle/curb heights differ. Furthermore, a concern exists that AVs may pose a perceived or real safety threat to pedestrians with visual disabilities navigating near or around AVs (Stantec and Applied Research Associates 2020).

Kuzio (2021) noted that the current cost of paratransit can be a deterrent for riders with disabilities and older adults and that both the cost and extent of the accessible design of on-demand SAVs are concerns for these populations. Specifically, Kuzio expressed concerns that fewer wheelchair-accessible AVs will result in longer response times, reliability challenges, and a higher price for riders, particularly in low-density, rural areas. Considering that current AV design is occurring in the private sector without significant input from paratransit riders, scholars speculate the lack of inclusion during the design process will widen the accessibility gap for people with disabilities.

Tabattanon and D'Souza (2021) evaluated retrofits of early test deployments for shared AVs specifically because many first-wave deployments were not designed to accommodate people with various types of disabilities. Retrofitting AVs to include ramps can sometimes have the negating effect of making exit and entry of the vehicle more difficult for ambulatory users while improving accessibility for users of wheelchairs and walkers. The authors noted that subsequent deployments have improved accessibility through additional features such as ramps, audio cues, and passenger announcements. Research also recommends accounting for accessibility accommodations early in the design process and moving toward universal design in AVs to ensure accessibility for most passengers; the other benefit of universal design in AVs is that their benefits can be used by all people (Feeley et al. 2020; Fraade-Blanar et al. 2021). Focus groups working with persons with autism and other disabilities stated that AVs should be designed as fully accessible and include features available in modern transit buses, such as kneeling, ramps, and/or lifts (Feeley et al. 2020).

Despite the challenges involving physical accessibility in private AVs, companies have begun researching and developing more inclusive AV designs through participatory processes. Stantec and Applied Research Associates (2020) noted that Lyft and Aptiv are working with the visually

disabled community to include AV features such as braille guides in future vehicles. The AV company May Mobility designed a wheelchair-accessible AV prototype to be tested for deployment, while AV company Local Motors (no longer in business) developed a prototype designed to communicate with passengers that can be used by people with disabilities.

To ensure accessibility and safety, Kuzio (2021) suggested that accessible AVs could include extra maintenance and safety checks (already required under federal law) to make sure that entry/exit infrastructure (e.g., ramps) is working properly in both urban and rural areas. Federal law has additionally integrated paratransit AVs into MaaS networks that combine public and private entities. An early example of this is the partnership between the City of Grand Rapids, Michigan, and May Mobility to provide wheelchair-accessible AV/SAV shuttles on request. However, inequities remain in the implementation of integrating paratransit AVs, and work still needs to be done in this area to attain equitable transportation outcomes.

To provide convenient, predictable, and safe accessibility options for older adults and riders with disabilities in urban and rural areas, the demand-response nature of current paratransit could transition to AV/SAV networks via automated shuttles, online and app-based booking, and real-time tracking (Kuzio 2021). However, if AV/SAV networks rely on webpage and app-based bookings, an accessible interface that accommodates visual, auditory, and cognitive disabilities is necessary for an inclusive and accessible AV/SAV design.

The U.S. DOT establishes accessibility requirements under the ADA for vehicles used in service to the public, whether operated privately or publicly. Existing requirements for buses, vans, and systems apply equally to SAVs. For new types of vehicles heretofore unseen, U.S. DOT ADA regulations require that standards be developed by the U.S. Access Board and U.S. DOT in concert before deploying such vehicles in use.

The accessibility of public rights-of-way is under the jurisdiction of the U.S. Department of Justice, via its regulations implementing Title II of the ADA. State DOTs have the power to implement regulations requiring accessible pedestrian infrastructure for designated drop-off spots in urban and rural areas before AV/SAV deployment. Additionally, a 2016 federal policy set out by U.S. DOT and the NHTSA stated that AV/SAV riders do not require a license, which should be enforced at the state level to remove an additional barrier to access. AVs must be ADA-compliant to be able to provide inclusive and accommodating travel services for older adults and travelers with disabilities in the United States. Some cities, such as Seattle, which requires a certain percentage of shared AVs to be ADA-compliant, have made additional regulations beyond what is required by the ADA for AVs/SAVs to ensure accessibility for all travelers (Emory et al. 2022).

Social Barriers

Social barriers to new mobility services include challenges such as user perception and understanding, safety concerns, and issues of service provider neglect.

Perception and Understanding

McNeil et al. (2017) conducted a survey and discovered a range of barriers related to limited or incorrect knowledge of new mobility services:

- "34% of lower-income respondents of color said that not knowing enough about how to use bike share was a big barrier to using it, compared to 19% of higher-income respondents of color and 7% of higher-income white residents."
- "18% of respondents thought that a helmet was required to use the bike share system [but none of the cities included in the study required helmets]. Lower-income respondents were more likely to make this incorrect assumption."

- "Most respondents indicated that they had 'no idea' about the cost of using the system and the availability of the reduced-price membership or pass option."
- "Even when cash options are available, most residents think a credit card is required to use bike share (and lower-income people of color were least likely to know cash was an option, if it was)."

Understanding how to use new mobility options (scheduling a trip, finding a vehicle, etc.) can be a large barrier for many historically underserved population types, particularly older adults unfamiliar with the technology (Mohebbi et al. 2021). A survey of low-income communities in Michigan found that low technology self-efficacy can be a more serious barrier for historically underserved populations than not having a bank account, smartphone, or internet access to use the service (Yan et al. 2021). Focus groups conducted in Buffalo found that a lack of understanding about where to find vehicles or have direct access to the vehicle was a barrier for older adults and persons with disabilities; additionally, persons with disabilities had issues with being able to coordinate pickups with TNC drivers and not being able to monitor their ride effectively while in the vehicle through the smartphone app (Yaffe 2020). The information describing new mobility options is universally available in English but may not be translated for people who are more comfortable speaking other languages, which results in limited understanding of the services among non-English speaking users (Cohen and Cabansagan 2017; Goodman and Handy 2015; Shaheen et al. 2017; Ursaki and Aultman-Hall 2015).

Active modes of travel frequently struggle to include users who do not identify as "epic outdoor folks" or "people in spandex" (Howland et al. 2017)—a factor that may lead potential bikeshare and scooter-share users to avoid the services because they do not see them as an option for themselves (Beale et al. 2022). Other researchers determined that limited cycling skills (Goodman and Handy 2015) and confusion about how bikeshare systems work present barriers to potential bikeshare users (Howland et al. 2017; Stewart et al. 2013; Ursaki and Aultman-Hall 2015). A survey of respondents in Portland found that some residents were concerned about how bikeshare systems worked, including misconceptions about requirements for credit cards and vehicle locking once time limits were reached (Beale et al. 2022). Analysis of a survey of persons with visual disabilities in the United Kingdom found that public information campaigns need to emphasize benefits of independent mobility and safety features to encourage adoption of future AVs by these populations (Bennett et al. 2020).

A significant barrier to AV/SAV adoption and deployment is public perception (or actual feelings) of being unsafe due to distrust in AV technology, the lack of a driver, or fears about unknown riders when sharing AVs (Stantec and Applied Research Associates 2020). Regarding distrust in the technological capacity of AVs/SAVs, a study conducted by Paddeu et al. (2020) found that participants felt SAVs would be inherently safer than human drivers but that complex traffic situations might be better navigated by a human (interacting with pedestrians, bikes, etc.). Participants had additional concerns about motorists and other modes navigating around/near an SAV and potential crashes resulting from human error. Focus group research from Hwang et al. (2020) found that persons with disabilities are concerned about communication between the human and the vehicle and about AVs being able to accommodate communication needs for different types of disabilities rather than generalizing these types. Without a human attendant on board the AV, the vehicle design will need to incorporate provision of onboard information to persons with different types of disabilities; this step can be a challenge for persons with cognitive disabilities, who often have a combination of sensory disabilities as well. Some passengers may need continual/repeated information if they have limited memory or are prone to easy confusion (Riggs and Pande 2021). A two-way communication interface in the AV may also help some passengers feel better because they have available support assistance from a live operator (Feeley et al. 2020).

An additional fear related to sharing AVs noted in the Stantec and Applied Research Associates (2020) report is the concern that shared or subscription-based SAVs may create problems due to riders' issues of perceived safety with other riders. Studies have shown that African American male riders experience longer wait times and higher cancellation rates for TNC services, while women are more likely to be driven on longer, more expensive routes. Language and cultural barriers can also create safety and discrimination concerns for riders in shared SAVs, particularly for non-English-speaking riders.

To normalize shared mobility before AVs/SAVs are launched, shared mobility for current transportation modes should be integrated and emphasized (Emory et al. 2022). This action can reduce the perceptions of feeling unsafe associated with sharing vehicles with strangers and can decrease the cost of eventual SAV services.

To combat the perception of feeling unsafe, Emory et al. (2022) suggested implementing developer/design safety requirements and considerations for those with perceived or real safety risks (e.g., women, racial/ethnic minorities, non-English-speaking populations) in shared AVs. The risks can be ameliorated with safety designs such as cameras, designated safe-space drop-offs, attendants in vehicles, or seat controls/voice controls to send alerts in an emergency (Feeley et al. 2020). A programmed safe word for vehicles to direct AVs to the closest police station could be an additional mechanism for voice controls to improve safety for passengers (Wu et al. 2021). Research with persons with disabilities found that in a hypothetical AV service setting, voice instructions and controls were preferable to braille writing (Brewer and Ellison 2020). Tabattanon and D'Souza (2021) noted that accommodations to allow service animals and personal care attendants in vehicles may be particularly important to some persons with disabilities who use AVs in the future. Furthermore, Paddeu et al. (2020) noted that low-speed SAVs helped improve users' perception of safety.

Regarding improved safety outcomes, AVs/SAVs may help prevent avoidable traffic crashes. In rural areas, in particular, there are higher rates of traffic fatalities on rural roads, largely resulting from speeding or alcohol use. If significant investments were made in AV/SAV network deployment in rural areas, these fatalities could be reduced (Emory et al. 2022). These efforts have already begun in Florida and Washington, where a Florida MPO and Washington State DOT have enacted policies to promote agency deployment of SAV shuttles in rural areas (Emory et al. 2022).

Emory et al. (2022) also pointed to the indirect health benefits of electric AVs/SAVs, which include reducing congestion and pollution effects from added VMT, thus protecting low-income and minority populations who are disproportionately exposed to air pollution created by the burning of fossil fuels. The authors suggested incentivizing electric AVs/SAVs, removing parking minimums and instituting parking maximums to control vehicle usage, and aiming to decrease negative environmental externalities that influence vulnerable populations. City governments that have already signed on to electric AVs/SAVs include Seattle DOT and the Association of Bay Area Governments, which require AVs/SAVs operating in the region to be fully electric, and the Louisville Metro Government, which is formulating plans to expand existing EV charging stations for future AV/SAV deployment.

Participatory research and community engagement can be used to inform equitable AV/SAV policy and determine the level of technology accessibility, especially for transportation-disadvantaged populations (Emory et al. 2022). For populations with disabilities and older adult populations, participatory design can be used to ensure the design matches the needs of all users (Paddeu et al. 2020). Although some state and regional agencies have mobilized equitable AV/SAV policy, many more have considered but not yet implemented these policies (Emory

et al. 2022). It is vital for both AV/SAV success and equitable AV/SAV outcomes to launch early-stage, inclusionary development and design efforts. These efforts can include multilingual public engagement/user-experience events, pilot studies with transportation-disadvantaged populations, partnerships with transportation advocacy groups, and educational information for government and community leaders alike (Stantec and Applied Research Associates 2020). Empowerment models of public engagement help community members have the information they need to make informed decisions and provide input to projects; this model can help overcome barriers in community engagement for AVs that have historically been caused by systemic racism, sexism, ableism, and other exclusionary attitudes (Steckler et al. 2021).

A study by Kadylak et al. (2021) discovered that, as of December 2021, 75% of American adults were hesitant about AV/SAV usage. The most common reasons for AV/SAV hesitancy include a lack of trust in AV/SAV technology, safety concerns, and cost concerns (Zmud et al. 2016). Studies have also established that sociodemographic characteristics can inform people's perceptions and acceptance levels of AV/SAV technology (Zhigang et al. 2018). For example, a lack of trust in AVs/SAVs and safety concerns about driverless vehicles can be barriers to use for older adults and people with disabilities (Zmud et al. 2016).

Ward et al. (2017) examined the perceptions of AV/SAV risks and benefits across different age groups. The authors discovered that driving behavior and feelings toward driving technology differed by age group and that older adults felt that driving was risky and involved human error. Alternatively, younger adults felt that car safety features made them feel safer, and they possessed more AV/SAV knowledge than older adults. The authors also discovered that increased knowledge about AVs/SAVs was positively correlated with trust in technologies because the perception of risk decreased and the perception of benefits increased after watching an informational video about AVs/SAVs.

To increase AV/SAV acceptance by older adults, Ward et al. (2017) noted that the Baby Boomer generation has a significant amount of purchasing power and can buy personal AVs to prolong their independence. Although this may be true in some cases, marginalized older adults and older adults with less disposable income might not experience this benefit.

Ward et al.'s (2017) findings of older adult AV/SAV perceptions were echoed in a study by Kadylak et al. (2021), who discovered that older adults with higher educational attainment, limited transportation options, and positive attitudes toward technology were more willing to use AVs/SAVs. However, the study's participant composition was primarily composed of White and urban populations. To make findings about older adult AV/SAV perceptions more comprehensive, education efforts and outreach to non-White, non-urban, older adults who are (a) typically not new technology adopters and (b) more skeptical of technology might be beneficial in increasing acceptance and willingness to use.

The study by Kadylak et al. (2021) additionally found that the group most passionate about AV/SAV adoption was of urban, educated, younger men. Because educational attainment is correlated with income, it can be inferred that lower-income populations are less passionate and accepting of AV/SAV technology, as are rural populations, both of whom face higher transportation cost burdens.

Considering that user acceptance of AVs/SAVs and trust in autonomous technology is essential for successful AV/SAV deployment, an emphasis must be placed on public engagement, the sharing of information, and educational/user-experience opportunities for transportation-disadvantaged groups (Paddeu et al. 2020). Furthermore, demographic differences must be considered in designing and implementing AVs/SAVs, and more studies are needed to evaluate acceptance by varying social and economic groups (Zhigang et al. 2018).

Personal Safety

New mobility services often rely on unwritten social contracts that hinge on trust between users, service providers, and the community at-large—contracts ranging from accepting rides from strangers (ridesourcing and ridesharing) to traveling along sidewalks and roadways (bikesharing and scooter sharing) exposed to other people and the elements in ways not familiar to users of traditional transit or personal autos. Naturally, some users may not feel safe under these conditions (McNeil et al. 2021).

Studying bicycling as a mode, McNeil et al. (2017) found that, regardless of race/ethnicity or income, safety concerns are cited by nearly half (48%) of the people they surveyed as the biggest barrier to riding. Similarly, safety concerns influenced by poor infrastructure are also prevalent (Goodman and Handy 2015; Howland et al. 2017; Stewart et al. 2013). Some efforts to remove barriers to bikeshare include adding bikeshare stations in underserved communities to provide easier access to the system; however, according to Chavis et al. (2018), this type of access improvement is only one piece of a larger puzzle that hinges on safety: "Common concerns such as worrying about personal safety, not having a helmet, or being unsure about bicycle/scooter liability are significant barriers that are not overcome by more equitable placement of bikes or scooters in low-income neighborhoods."

Other personal safety concerns among new mobility users are related to gender and race. Women and people of color have been identified as especially vulnerable when using transit and new mobility options. In a review of a Los Angeles Metro report on women's travel, Halais (2020) highlighted how women, more likely to have lower incomes and to travel during times when transit service is slow (forcing them to wait in potentially dangerous locations), experience extreme risks when traveling. For example, according to Metro's data (which do not account for unreported assaults), 14 rapes were reported on transit lines between October 2017 and September 2018.

People of color experience frequent risk as a result of racism and bias that includes police violence and harassment by the general public. According to Brown et al. (2016), potential interactions with police while using bikeshare are cited as concerns by equity communities in several studies. Focus groups consisting of people of color and people with low incomes in Philadelphia documented uncomfortable or intimidating interactions with police, even in instances where the focus group participants were victims of theft or crashes (Hoe and Kaloustian 2014). The Community Cycling Center (2012) in Portland revealed that Latino/Hispanic and African immigrants fear racial profiling and the possibility of deportation as a result of their exposure when cycling. McNeil et al. (2017) further outlined the personal safety concerns experienced by people of color according to income level and compared to White residents:

> Race is an important factor in whether respondents feel their personal safety could be compromised, either as a victim of crime or as a target for police attention. For people of color, being lower-income further exacerbated safety concerns. For example, 22% of lower-income respondents of color stated that a big barrier to riding [a bicycle] was that doing so could cause them to be harassed or a victim of crime. This compared to 17% of higher-income people of color and 7% of higher-income white residents.

The implementation of AVs also presents the possibility for further racial inequity and safety issues due to existing biases. According to Wu et al. (2021), AV algorithms have been primarily trained for the technology to recognize pedestrians in the roadway using images of White people; this process has resulted in the side effect of the technology more accurately identifying White pedestrians than pedestrians with darker skin tones during AV testing. Naturally, if unchecked and not proactively corrected, such technology would increase the risk of non-White pedestrians being hit by AVs during a crash incident (Wu et al. 2021). Consequently, the implementation of facial recognition technology in AV/SAV design must consider discriminatory and systemic bias to ensure that certain groups of people are not excluded or put at risk as a result of the software.

Neglect

Neglectful operating practices—which are actions that give little attention or respect to service recipients—among ridesourcing drivers and companies result in racially motivated denial of service and preclude some new mobility users from accessing services. In a study analyzing disparities in wait times for ridesourcing trip requests, the authors discovered a correlated pattern of discriminatory behavior that resulted in wait times for African Americans that were as much as 35% longer and a higher rate of driver cancellations for riders who requested rides with names that were interpreted to be names associated with an African American customer (Knittel et al. 2016). In Boston, Uber drivers were found to cancel rides requested by male users with "black-sounding names" at twice the rate of cancellations for "white-sounding names." Ironically, in an indication of the potential for corporate culture to possibly bias service provision, the same study found that Lyft drivers did not show the same levels of discrimination (Cohen and Cabansagan 2017).

Inclusion-Focused Policies and Goals for New Mobility

New mobility providers initially deployed vehicles and operated in cities independently of local government controls and initiatives. However, popularity of services such as TNCs and scooter share has increased in urban areas, and cities have begun to consider the ramifications to both their transportation systems and the inclusivity of new mobility options for all residents. Some cities primarily focus on transportation costs as the driving factor for investment and planning decisions, but this thinking can lead to an inequitable distribution of mobility benefits to different system users (DeGood and Schwartz 2016). Meanwhile, city transportation systems and underserved populations are affected by the disruption of new mobility providers to previously existing services. Taxicab companies operating in cities are much more likely to allow cash payment and provide WAVs as part of their fleet than TNCs. As TNCs take a greater share of the for-hire transportation market from the taxi industry, the result may mean fewer travel options available for persons with disabilities or lower incomes (Committee for Review of Innovative Urban Mobility Services 2016).

Meanwhile, many transit agencies have engaged in partnerships with TNCs and other new mobility companies to provide service alternatives to transit. These alternatives can include cutting bus lines with low ridership and replacing them with subsidies for TNC fares. These partnerships are often done as a pilot project to prove the concept of service, which can mean they involve conducting an equity analysis or providing full inclusion to the service (Cohen and Cabansagan 2017). Likewise, the gradual introduction of AVs might result in lower ridership for transit, meaning available funding to support transit will likewise decrease (Kaplan et al. 2017). Because decision-making power is unevenly distributed across communities, the result of these initiatives can produce side effects in mobility inclusion even when there is not ill intent (Tibbits-Nutt 2019).

Stated Policy Goals

Some cities have begun to develop definitions of inclusive transportation and/or policy goals to increase the inclusivity of transportation for underserved populations. Policy goals can include bridging the digital divide, extending access to unbanked and underbanked users, or mandating accommodations for passengers with special needs (Shaheen and Cohen 2018). A report from EDR Group (2019) states that comprehensive accessibility definitions will address three dimensions:

1. "The user group, defining the perspective of the measure (including the level of spatial aggregation)."

2. "The attractions, destinations, or opportunities to which access is being considered."
3. "Network availability and performance, which dictates whether trips are possible by a given mode and the 'impedances' (i.e., travel distance, time, cost, reliability, etc.) that limit access between users and attractions/destinations."

A report prepared for the Los Angeles Department of Transportation states that to grow shared mobility in the city, the agency should balance the needs of existing ridership with attracting new customers (Hand 2016). The report discusses several potential policy recommendations for improved shared mobility use, including the following, which focus on improving equitable access:

- Adopt a customer bill of rights and metrics for transportation happiness.
- Create a user experience working group.
- Engage the entire community on infrastructure condition assessments.
- Prepare the workforce for changes driven by innovation in transportation technology.

Research conducted for U.S. DOT includes the following proposed policy strategies to help address the barriers hindering inclusive access to shared mobility (Shaheen et al. 2017):

- Require shared mobility operators to locate services in neighborhoods with service gaps as a condition of operation of public right-of-way.
- Introduce risk-sharing partnerships for locating vehicles in potentially less profitable areas.
- Require self-service vehicles such as carsharing and micromobility to be available at all times of day.
- Facilitate off-peak commuting partnerships for late-night workers.
- Reduce taxes and fees for shared mobility services that benefit low-income users.
- Subsidize access to shared mobility for qualifying users.
- Provide pre-tax commuter benefits for shared mobility use.
- Deploy shared mobility access kiosks for users without smartphones.
- Offer alternative access such as concierge services or SMS text access for persons who do not have a smartphone.
- Switch transit fare payment systems to be account-based, allowing users to transfer transit subsidies to other services.
- Define multiple tiers of accessible vehicles for users with special needs.
- Provide assisted rides for users needing assistance at either end of a trip.
- Shift to performance-based community engagement metrics that ensure broad participation from community members.
- Require ongoing evaluation and refinement of shared mobility services according to equity goals.

Despite the uncertainties surrounding AV/SAV implementation, local, state, and federal governments all acknowledge the necessity for design and development regulations in advance of AV/SAV deployment. Existing regulations are, and future regulations will be, influenced by the proposed benefits (e.g., decreased travel cost, increased connectivity, and enhanced safety) and potential risks [e.g., increased VMT, pollution (if non-electric), urban sprawl, and congestion] of AV/SAV technology (Freemark et al. 2020).

Local governments are beginning to include AV technology in municipal plans despite AV implementation uncertainty, and many have additionally engaged in AV/SAV testing efforts (Berliner et al. 2019). Municipal governments have influence when it comes to street design and new and emerging transportation technologies (e.g., connected vehicle infrastructure). Cities have different regulatory jurisdictions, and public transit agencies also come into play at the municipal level (Freemark et al. 2020).

A study by Freemark et al. (2020) measured local government officials' perceptions of AV/SAV policies supported by literature but not often used in practice. Local officials supported AV/SAV policies focused on the right-of-way (e.g., expanding pedestrian infrastructure), equity (e.g., increasing access for low-income populations), and land use (e.g., reducing sprawl). Officials pointed to these policies as being within local municipal power but highlighted a gray area of bureaucratic limitations beyond these policies due to constraints in local power. However, local governments did feel that the political feasibility of AV policies would gain support over time and would help foster the integration of other equity-adjacent policies that have yet to be implemented, such as congestion pricing.

State governments have the power to regulate AV/SAV piloting and testing but not most vehicle design or safety standards (states can regulate window tinting, for instance) (Kuzio 2021). Similar to local governments, state governments have also begun to introduce legislation related to self-driving vehicles. As of May 2021, 38 states had passed AV/SAV legislation and 23 had created AV/SAV requirements for operators, testing, and public road use (Center for Strategic and International Studies 2021). However, the state-by-state patchwork of different rules and regulations makes standardization difficult. Currently, no federal mandates or regulations exist that specifically focus on AVs/SAVs. Instead, interpretations of NHTSA/U.S. DOT vehicle safety and operating mandates inform federal guidance. This guidance includes U.S. DOT and NHTSA's Automated Driving Systems 2.0 and NHTSA's Vision for Safety 2.0, both of which feature voluntary AV/SAV safety policy guidelines (Brinkley et al. 2019).

In terms of accessibility, both public and private entities are subject to U.S. DOT ADA regulations, though the specific requirements differ according to whether or not the private entity is primarily engaged in the business of transportation. SAVs themselves are governed by existing U.S. DOT ADA requirements for buses and vans, codified at 49 CFR Part 38, Subpart B. New technologies may, however, include service models and vehicle types that may not fall under existing regulations.

Lewis et al. (2017) cited additional AV/SAV policy considerations. In terms of fostering trust among populations who are distrustful of technology in general or in AVs/SAVs specifically (e.g., older adult populations), U.S. DOT can institute preemptive privacy regulations, and state and local governments can institute data-sharing agreements. Regarding improving AV/SAV safety and reducing the perception of AV/SAV dangers for populations concerned about the lack of a driver (e.g., populations with disabilities or non-English-speakers), the federal government can include AV/SAV technology implementation in the eligible list of federal safety programs. Staffing for SAVs can also be made an eligible operating expense for public entities under FTA grant programs.

Last, when considering concerns about degradation to the environment and decreased accessibility, particularly for populations that disproportionately carry pollution burdens (e.g., low-income populations, minority populations, and limited-English speakers) and populations with poorer transportation accessibility (e.g., populations with disabilities, rural populations), the federal government can create a discretionary grant program focused on transportation projects that meet environmental and accessibility goals. For example, federal grant programs such as U.S. DOT's Smart Cities Challenge and MOD Sandbox incentivize state and local governments to partner with private industries to research and implement ways in which AVs/SAVs can improve environmental protection and enhance accessibility (Lewis et al. 2017).

Policies or Regulations Facilitating Goals

This section of the review focuses on examples of specific city or other government organization policies or regulations aimed at facilitating equity-initiative goals. Equity initiatives can

fall under the category of either focused equity programs or inclusive access initiatives (Peterson et al. 2019). Focused equity programs are services specifically designed to meet the needs of a specific group. These can include ensuring eligibility of low-income customers or providing on-demand neighborhood services in places without transit. Inclusive access initiatives aim to make regular shared mobility services more accessible to everyone. Such initiatives include offering discounts on fares or enforcing distribution requirements for shared vehicles.

Inclusive Access

Inclusive access can start with ensuring that new mobility vehicles and drivers are available in areas that are underserved by transportation options by developing city policies that provide and stage vehicles in these areas; this process can include requiring adaptive micromobility vehicles for persons with disabilities (Reinhardt and Deakin 2020). For older adults and persons with disabilities, locating services near senior housing facilities, group homes, and other similar housing places (potentially with designated stops or stations at these locations) is an important first step for improving access; Valley Go in the Central Valley region of California is an example of a carsharing program with this strategy (Yaffe 2020).

Many local governments build equity objectives into their permitting processing by requiring targets to be met through annual permit processes or licenses (Peterson et al. 2019); the same could be done in the future with the implementation of AVs (Wu et al. 2021). Examples of the incorporation of equity objectives into the permitting process include the following:

- The City of Denver's Department of Public Works passed a regulation requiring carshare companies to place vehicles in areas with 30% or more of the population below the poverty line (called "opportunity areas") (Kodransky and Lewenstein 2014).
- Chicago's e-scooter pilot program requires scooter companies to distribute half of their e-scooter fleets within the designated priority areas to ensure accessibility to underserved community areas. The city's scooter report noted that none of the 10 companies have consistently met the requirement for their first deployment in the morning, but rebalancing requirements have appeared to increase e-scooter availability in these communities (City of Chicago 2021).
- Washington, DC, has required carshare providers to locate vehicles in low-income neighborhoods as well (Committee for Review of Innovative Urban Mobility Services 2016).

Likewise, funding can also be a key mechanism for enabling more service in underserved communities, including subsidies to place vehicles or stations in lower-income neighborhoods (Ursaki and Aultman-Hall 2015). One example of an innovative funding mechanism is a California Air Resources Board initiative to help fund carsharing pilot projects in disadvantaged communities using funds from the state's cap-and-trade program (California Air Resources Board 2015; Committee for Review of Innovative Urban Mobility Services 2016).

Carsharing programs have traditionally limited membership to persons with a current driver's license so that all members can drive the vehicle. However, this limits access for historically underserved populations. Allowing membership to non-drivers and assigning drivers to their accounts can improve access. In this structure, non-driving members can be responsible for making reservations, billing, and all other non-policies and procedures while taking on legal responsibilities assigned to the drivers; these members will still undergo background checks and approval processes. The dedicated drivers will be covered under member policies and insurance from the operator and thereby incentivized to participate (Yaffe 2020).

Cities and community partners in bikeshare programs have some of the most visible examples of inclusive access in new mobility. The Better Bike Share Partnership (BBSP) is a collaboration between Philadelphia and community partners aimed at bringing bikeshare to underserved communities, particularly communities of color and lower-income individuals. BBSP placed

bikeshare stations in lower-income and racially diverse neighborhoods and conducted targeted outreach in underserved communities. Just Rides is a program between Charleston, South Carolina, Gotcha Bikes, and community advocacy agencies aimed at ensuring access to bikeshare for low-income residents, including by adding stations to targeted neighborhoods and prioritizing rebalancing at these stations (McNeil et al. 2019). The SoBi program in Hamilton, Ontario, has an explicit equity initiative, "Everyone Rides," that added new stations and bicycles in low-income neighborhoods (Hosford and Winters 2018).

Outreach and rider education can be key for enabling underserved communities to learn how to use services. Just Rides uses community ambassadors, group rides, and other educational programming to engage and open opportunities for lower-income residents (McNeil et al. 2019). The Everyone Rides initiative includes education and outreach activities as well (Hosford and Winters 2018). Private companies sometimes do outreach and marketing directly to underserved areas. In 2019, Uber launched a strategic marketing campaign targeted at lower-income neighborhoods in the New York City outer boroughs, specifically messaging to areas with limited transit access (Atkinson-Palombo et al. 2019). However, independent programs like this are typically either the exception or limited to the launch period rather than being an ongoing component (similar to the accessible bikeshare pilots discussed elsewhere in this report). To further encourage supportive programs, Shaheen et al. suggested that cities and DOTs should also consider adopting a customer bill of rights to help ensure equitable service (Shaheen et al. 2017).

Late-Night Access

Another advantage of newer shared mobility options is the ability to provide additional travel options at later times in the day and evening than traditional public and private transportation services, particularly through the ease of hailing or finding vehicles via mobile technology. Public transit agencies typically reduce or cut service later in the day after peak commuting periods end due to a lack of demand and increased costs, creating a coverage gap for shift workers in the evening. The Massachusetts Bay Transportation Authority (n.d.) conducted a study that listed goals to (a) establish funding for programs dedicated to supporting late-shift transit operations, (b) embrace innovative partnerships to meet late-shift mobility needs, and (c) create frameworks to allow employers to subsidize late-shift period transit. Pinellas Suncoast Transportation Authority (PSTA) and New York Metropolitan Transportation Authority (MTA) are both conducting pilot programs to provide rides for late-shift workers through private providers. PSTA's TD Late Shift provides free rides on Uber for qualified riders (Uber 2017). Washington Metropolitan Area Transit Authority (WMATA) began a 1-year pilot program with Lyft in 2019 to help with coverage in the early-morning service on WMATA rail for qualified riders at a capped rate of 40 free trips per month (Glambrone 2019).

Shared mobility providers can also provide bonuses/incentives for drivers to service low-income or other underserved areas. A study of ridehail data in Chicago found that Uber used "boost zones" and Lyft used "personal power zones" to increase rates for drivers to service trips in neighborhoods identified by the platform. This strategy for higher pay to drivers may help encourage service to areas away from higher-demand places and provide more equitable service for riders, so long as the additional incentive for the driver is not passed through to the rider as a higher fee for service (Pandey and Caliskan 2021).

Equity Policies

Equity policies and goals help ensure increased access to service for underserved or discriminated-against individuals, either through equality of opportunity or equality of outcome (Peterson et al. 2019). For example, people of color and women can experience significantly greater challenges when traveling on public transit or using shared mobility services. Some

cities have created equity mandates and/or requirements within permitting that require micromobility operators to locate a specified portion of vehicles in underserved areas (Samsonova 2021). San Francisco includes an equity component in its permitting program for scooters; the city requires providers to have a low-income membership option, encourages deployment of scooters in underserved areas, and requires that multilingual information be posted online (Maguire 2018). Transport of London has adopted an equality and inclusion policy with measurable goals for improving experiences for transit users (Halais 2020). Indego in Philadelphia uses a station report card to grade each station via performance measurements, including measures on equity that are based on the percentage of riders with reduced rate passes, people of color, or low-income individuals (McNeil et al. 2019). Private mobility companies themselves frequently have policies on equity and inclusion. A 2017 study found that one in four bikeshare systems had written policies on equity, while many more systems consider equity as part of their system in terms of station siting, fee structure, payment systems, and promotion and marketing (Howland et al. 2017).

Discounting Memberships/Fares

Some programs for increased access to new mobility offer reduced and lifted fares or membership/application fees, including monthly subscriptions or pay-per-trip options (Peterson et al. 2019). These options help offer lower initial entry cost for trying the service, mimic fare pricing of public transportation, or reduce the burden of fees for longer rental times; moreover, offering free trials to users can be a low-risk method for underserved populations to learn about the service and see whether it works for their trip needs (Pan and Shaheen 2021). Just Rides and BBSP have both used discounted membership options or changes in pricing structures to help low-income riders (McNeil et al. 2019). SoBi in Hamilton, Ontario, and Baltimore's bikeshare has also offered free or subsidized memberships for low-income residents (Chavis et al. 2018; Hosford and Winters 2018). The Jobs Access Program between Lyft and nonprofit Philadelphia Works issues $10 ride credits for clients who are looking to secure employment or training but are outside of public transit service (Murphy 2019).

New mobility services can also offer options for customers to pay either per single trip or through a weekly or monthly membership, as is provided by Baltimore's bikeshare program (Chavis et al. 2018). Bikeshare users in low-income neighborhoods may have higher average trip costs due to their travel distance needs, causing financial barriers for further use and membership; operators can help alleviate these burdens with reduced fees, early-stage promotions, or longer time limits for free rides (Qian and Jaller 2020). Monthly memberships help reduce the large upfront cost of an annual membership to a new mobility service (Howland et al. 2017; Pan and Shaheen 2021). Allowing low-income individuals to pay for annual memberships in installments helps overcome large one-time payments that present an overburdensome barrier (Goodman and Handy 2015; Martin et al. 2020). Simplifying pricing structures for fares/memberships to be more straightforward and understandable is another policy to consider for further system adoption (Deakin et al. 2020). Additionally, discounted memberships/fares to shared mobility for transit users can help encourage use by historically underserved populations; the Bike + Bus Pass program in Kansas City, Missouri, offers unlimited bikeshare rides (up to 60 minutes each) for users with a monthly bus pass (Patterson 2020). Some transit agencies have used the practice of trip capping—setting a maximum amount for fare purchases in a month and allowing free travel once a rider has reached the monthly pass cost—to help curb inequity caused by fare pricing structures. The literature search found no examples of explicit fare-capping practices by new mobility companies.

Some private companies also have discount programs to help incentivize low-income riders to use their services. These programs, which include free memberships or discounted passes,

are based on proof of eligibility or participation in a state or federal assistance program by the applicant rider. McNeil et al. (2019) documented the following examples of discount programs from new mobility companies:

- Lyft's Community Pass program offers unlimited rides (up to 30 minutes) for a $5 monthly membership.
- Lyft, in partnership with Uninterrupted, provides free 1-year bikeshare memberships to qualified teenagers through YMCA locations (Lyft 2020).
- Lime's Lime Access program offers 100 rides for $5 for a standard bike or 50% off rides on e-bikes.
- Pace/Zagster offers $5 monthly memberships for low-income riders.

Some micromobility programs offer eligibility for discounted memberships/rides based on current participation in government benefit/assistance programs (Samsonova 2021). Boston's bikeshare system, Bluebikes, introduced its SNAP Care to Ride program in January 2018, which offered discounted membership to SNAP participants at $5 per month, or $50 per year, for unlimited trips up to 60 minutes in duration. SNAP Care to Ride was subsequently expanded to include participants of other local government assistance programs; participants could either sign up online or in person at guided enrollment centers. A study of the program found that bikeshare access increased across the city following the program launch, but gains of access were proportionally smallest in communities with the highest need. However, results still represented a 27% increase in access for these communities (compared to 50% in other parts of the city). The authors speculated that additional stations are necessary for high-need communities to make the dock bikeshare service have better system connectivity (Soto et al. 2021).

In San Francisco, affordable membership plan options have helped boost participation in dockless bikeshare programs by low-income riders. Ford GoBike reported that 20% of its members took part in its Bike Share for All Program. JUMP Bike Boost Plan members took three times as many trips on average, while 55% of trips began or ended in an identified "community of concern" (Qian et al. 2020).

An evaluation of shared micromobility programs in Seattle recommended adopting a living income-based discount program that considers the cost of living in the city rather than the federal poverty level standard to account for the higher impact of transportation costs on low-income populations (Beale et al. 2022). Broadening the historically narrow definition of low-income populations in discount programs to include rent-burdened and other similar characteristics of financial strain can help to address barriers for populations with the highest need (Pan and Shaheen 2021).

Alternative Payment

In addition to cost, cities and companies have offered alternate forms of payment to help address challenges that unbanked or underbanked riders face when accessing new mobility services that require use of a credit card (Howland et al. 2017). These alternatives include integrated options for customers to use preloaded debit cards to pay for fares, thus eliminating the need for a debit card or bank account to use the service (Reinhardt and Deakin 2020; Shaheen et al. 2018). PayNearMe is a service used by Indego bikeshare in Philadelphia that allows riders to purchase a barcode for ride payment with cash at local convenience stores (McNeil et al. 2019). Dallas Area Rapid Transit (DART) uses a similar cash payment option for its GoPass mobile app. This solution does not allow the use of direct cash payment for fares, which is rare for new mobility services. However, Baltimore's bikeshare program, BikeArlington in Virginia, Lime, and Zagster allow for cash payment on their systems (Chavis et al. 2018; Committee for Review of Innovative Urban Mobility Services 2016; McNeil et al. 2019). Similarly, Just Rides

facilitated cash enrollment efforts to help underbanked customers sign up for the service (McNeil et al. 2019).

Bundled mobility programs allow users to pay for shared mobility services using a *travel wallet* that pays for multiple types of services; integrating fare payment options between public transit and shared mobility services can also help encourage utilization by low-income and other historically underserved populations (Pan and Shaheen 2021; Patterson 2020). Portland's Transportation Wallet program integrated micromobility services to the public transportation payment platform in this manner while providing prepaid cards to low-income individuals to use multiple services (Beale et al. 2022; McNeil et al. 2021). Importantly, public agencies and shared mobility providers should look for opportunities in which compatible technologies may allow integrated fare payment between services (Beale et al. 2022).

In addition to offering cash payment options that allow customers to pay for fares in a work-around to mobile apps and smart platforms, transit agencies and new mobility companies can help customers get easier access to electronic payment options that the platforms typically use (Committee for Review of Innovative Urban Mobility Services 2016). In Los Angeles, Bird allows customers to unlock vehicles using SMS text-messaging along with cash fare payment (Samsonova 2021). Baltimore provided free checking accounts for customers and removed holds on debit cards for casual users of its bikeshare system (Chavis et al. 2018). Some cities have formed partnerships with banks or credit unions to simplify access to checking accounts and provide a better way for unbanked riders to use new mobility services, though these partnerships are small and have limited impact on customers nationwide (Kodransky and Lewenstein 2014).

Community Education and Feedback

Lack of adequate information about how shared mobility services work and the benefits of using such services can be a barrier for many underserved populations (Leister et al. 2018). Language barriers for non-English or English-as-second-language speakers may be the key challenge in understanding the service when using the available customer education materials. Even simple measures such as advertisements with different types of users (backgrounds, age, fitness levels, etc.) can be useful to show that services are available to everyone (Martin et al. 2020). Programs to educate riders on how to sign up for and use new mobility services can help clear up misconceptions and answer questions about using the services. These programs may include classes and events conducted by staff, ambassadors, or community partners (McNeil et al. 2019). Such programs may be offered directly by the city/company or in partnership with local community organizations. For bikeshare programs, learn-to-ride classes can help novice riders learn the skills to ride the vehicle in their community environment. Educational programs can also discuss options for payment plans, cash payments, and adaptive/accessible needs available to riders (McNeil et al. 2019). Information centers with in-person customer service can be a tool to help educate people about new mobility options and safe use of the system (Auckland Council 2019; Ursaki and Aultman-Hall 2015). Likewise, community education should be offered in other languages to ensure equal access to information in the community (Kodransky and Lewenstein 2014).

Community outreach and education can help build relationships with local partners and improve the visibility and public support for new mobility options in communities that are not as willing to use them (Chavis et al. 2018; Ruvolo 2021). In some communities, additional investment in customer education about available shared mobility service options and discount programs can be more impactful for adoption by low-income populations than simply increasing the amount/presence of vehicles (Pan and Shaheen 2021). Detroit's MoGo program trains ambassadors on the bikeshare system and uses them to engage and encourage peers in the community to use and adopt bikeshare, coordinate group rides, and assist with customer surveys

(McNeil et al. 2019). Another use of education programs is to promote safety of new mobility options, such as providing free helmets for bikeshare users (Chavis et al. 2018). Education and orientation events can also provide an opportunity to get people signed up for a service, particularly services that require online access to set up memberships, by providing computer terminals and staff or volunteers to assist in the process (Chavis et al. 2018).

Community feedback can also be instrumental in helping cities learn about specific barriers to accessing new mobility services for lower-income individuals or other target populations. These outreach programs should be culturally appropriate for the groups targeted to use the service (Peterson et al. 2019). OakMob 101 in Oakland, California, is an example of a particularly dynamic program that engaged residents in the city's lower-income areas with low public transit and carshare service availability to learn about their needs for shared mobility companies. Workshops educated residents about shared mobility and collected feedback on barriers to accessing carshare and bikeshare services (Brown et al. 2017). New York City DOT crowdsourced recommendations for new bikeshare station placements to better locate stations in lower-income areas where residents recommended them (Kodransky and Lewenstein 2014). BBSP conducted interviews with community partners to build relationships, learn about the target user community, and build better connections to employment opportunities (Chavis et al. 2018). Civic inclusion models for participation and input into program designs can lead to buy-in from traditionally underserved populations to use the shared mobility service once it is available (McKinney 2020).

Planning

Effective cities use the planning process to develop goals and strategies for improving transportation in their communities. Because of the emergence of newer shared mobility options, transportation planning has started to include these travel modes and vehicle types, too. Successful planning for emerging mobility discusses how technology can help promote the goals of the city/agency, determine what culture change is needed, quantify potential costs and impacts, facilitate communication between stakeholder groups, and develop requirements for operators. Communities within the city/region, including underserved communities, should have the opportunity to participate in the decision-making process as well (Peterson et al. 2019). Planning principles to improve equity in decision-making and goal-setting include reframing traditional viewpoints of planning conversations, allocating funding and resources equitably, improving diversity in leadership, prioritizing underserved and underrepresented communities, and investing in communities without displacing people (Hanzlik and Schweninger 2019).

Beyond representation among decision-makers, data representation can also limit inclusion. If low-income, unbanked, and older adults, along with other underserved groups, are not using new mobility services, data on their travel patterns and needs may remain undetected and unreported. Connectivity via sensors or other communication technologies may help in gathering data to understand the precise travel needs of the underserved, as well as their preferred travel origins and destinations. On-demand services may then be tailored to address these mobility requirements. On the other hand, data emanating from connectivity may lead to inequitable outcomes. For example, service providers may price routes differently, depending on willingness to pay. Opting to take a cheaper route may take passengers on longer journeys, whereas those willing to pay more could access faster premium routes with better roads and more reliable journey times. A corollary impact of this differential pricing may be an increase in traffic volumes being routed through low-income neighborhoods, with associated congestion and collision risk.

Service planning and implementation are challenged by preemptive legislation (such as the statewide TNC laws in Texas), poorly developed service contracts, absence of service following the pilot period, and policies that lack consideration for local conditions.

Partnerships

Shared mobility partnerships have been a mechanism for cities and transit agencies to pilot new services and address existing transportation gaps in the community. Partnerships with private mobility companies work best when the public agency has clear objectives that are used to develop a detailed plan for the partnership. For example, some cities are already subsidizing ridesharing services as an effective way to address the scarcity of mobility options for low-income workers on night shifts. Other public agencies are working with technology companies to use real-time data to make bus routes more efficient and redirect the flow of public transit to the neighborhoods that need it most.

Baltimore formed a partnership with Lyft and community groups to improve access to grocery stores in areas of the city identified as food deserts. The pilot provides qualified residents with eight rides a month using the Lyft app for travel to grocery stores at a flat $2.50 rate (Descant 2019). Dakota County, Minnesota, partnered with Lyft to provide qualified residents on Medicaid waivers free rides to and from work. The partnership is focused on helping people with disabilities find work, particularly in areas without available or frequent transit service (Clarey 2019).

Cities should also involve third parties, such as community-based groups, businesses, and local champions, in the partnership to help with successful dissemination and diversity of investment (Peterson et al. 2019). Intermediaries or third-party brokers (such as advocacy groups or city departments) can help bridge the barriers to serving lower-income or disability communities by identifying barriers, providing solutions, and offering outreach to the community (Kodransky and Lewenstein 2014).

Technology Access

Another frequent barrier for underserved communities is technology access, which has been exacerbated as new mobility options have driven the use of smartphones and availability of internet access and data plans to be nearly required for riders to use shared mobility services. However, cities and companies have found some solutions for easing the barriers in technology created by new mobility services. Concierge services for customers to make trip reservations and payments can also help overcome other technology and payment barriers for customers; tracking of completed pickups and drop-offs on a ridehailing service can be an additional step to ensure customer safety (Deakin et al. 2020).

Many partnerships for ridehailing or microtransit include a call center option to allow customers to request rides by phone rather than through a mobile app, while Lime's Lime Access program in New York City allows riders to unlock e-scooters using a text-to-unlock feature, which means they can simply send a text message to a designated phone number for unlocking, eliminating the requirement of owning a smartphone (Lime 2019). If call centers/concierge services are established for new mobility services, having call-takers in common non-English languages is another important step to ensure access for historically underserved populations (Deakin et al. 2020). Improving accessibility within the technology for additional features, such as voice-activation compatible features in the smartphone application for persons with disabilities, is also necessary (Yan et al. 2021).

In-person enrollment or paper application processes such as those at Ithaca CarShare or dockless bikeshare in San Francisco allow applicants without internet access to sign up (Kodransky and Lewenstein 2014; Martin et al. 2020; Qian et al. 2020). However, little is found in the literature about improved access to internet and cellular networks in areas with poor coverage, which in turn lessens the ability of affected residents to request rides on demand.

Incentives and Subsidies

Subsidizing the cost of AVs/SAVs and providing a more equitable pricing structure for AV services can benefit low-income and rural populations and can be used to incentivize the shared use of AVs. Allowing for multiple payment options will also remove barriers to access for low-income populations, unbanked/underbanked populations, and populations without access to a smartphone or credit card. AV/SAV operators can additionally be required to provide service to transit-scarce urban areas and rural areas as a public right-of-way operating condition. The enactment of these regulations can be used to distribute service more equitably, particularly for low-income and rural populations (Stantec and Applied Research Associates 2020). Incentives for current shared mobility providers to locate carsharing or micromobility systems in low-income communities are another tool for cities to reduce spatial inequality (Deakin et al. 2020; Martin et al. 2020). Another incentive may be reducing or eliminating taxes (such as car rental taxes that are applied to carsharing services) so that operators will locate their services for local residents (Martin et al. 2020).

Policies or Regulations Preventing Goals

Some policies and regulations put into place by city and state governments on new mobility options can have negative consequences by creating or reinforcing barriers to underserved populations wanting to use the services. City intervention in the supply of vehicles via permitting without specific requirements to ensure service in all parts of a city can create issues with limitations on the span of service or preferential service provision by the private mobility company due to such companies' pursuit of the highest level of demand and user income, consequently leaving a lack of service provision or available vehicles in lower-income areas (Cervero 2017). Caps on shared vehicles and high insurance requirements can also limit the number of providers available to users, thereby facilitating monopolies for larger private companies and decreasing the amount of competition available to improve equity of shared mobility options. Insurance options for shared mobility services that alleviate costs for operators can be another way to lessen barriers to entry into local markets (Martin et al. 2020).

For ridehailing/TNCs, a majority of state legislation preempts the local city authority's ability to regulate, tax, or impose rules on TNCs (Moran et al. 2017). These state regulations with preemption limit the ability of cities to require service provision and accessible vehicle options in underserved neighborhoods. Currently, most states do not have legislation in place governing micromobility modes such as bikeshare and scooters; passing similar preemptive regulations for micromobility could lead to additional barriers in service equity created by policy. For carsharing and bikesharing, cities with their own programs often have membership fees required to use the service. Any membership fees that are set at an annual payment rate present a barrier for lower-income individuals, who may struggle to afford the service at a high one-time cost (Goodman and Handy 2015).

In general, jurisdictional rules and requirements related to new mobility vary, which can potentially challenge service providers and limit or hinder access for some groups (Deakin et al. 2020). However, despite some existing literature that describes jurisdictional issues associated with new mobility, none of the work deals with jurisdictional issues from the perspective of underserved communities. The following is a list of some of the existing literature:

- *TRB Special Report 319: Between Public and Private Mobility: Examining the Rise of Technology-Enabled Transportation Services* discussed issues of jurisdictional rules on TNCs but is not related to equity (Committee for Review of Innovative Urban Mobility Services 2016).
- *TCRP Research Report 202: Handbook for Examining the Effects of Non-Emergency Medical Transportation Brokerages on Transportation Coordination* discussed issues of non-emergency

medical transportation coordination across jurisdictional boundaries but does not discuss transformational technologies in transportation (Edrington et al. 2018).
- *Policy Implications of Transportation Network Companies* discussed state statutes on TNCs and preemption of local rulemaking as a possible mechanism for eliminating patchwork requirements by jurisdiction (Moran et al. 2017).
- *Examples of MOD Policies and Public-Private Partnerships to Increase Accessibility* included the Vermont Agency of Transportation's FTA MOD Sandbox project as an example of a technology that can help with trip planning across jurisdictional boundaries. The project developed General Transit Feed Specification (GTFS)-Flex data for public transit but did not involve any new shared mobility modes (Benedict et al. 2020).
- *Opportunities for Shared-Use Mobility Services in Rural Disadvantaged Communities in California's San Joaquin Valley: Existing Conditions and Conceptual Program Development* developed a concept for a technology platform that would aggregate multiple demand-responsive transportation services (Rodier and Podolsky 2017).

Metrics to Measure Progress

Metrics in shared mobility are relatively new, and unlike other public transportation, there are no set standards tailored to new mobility services. Cities and transit agencies are accustomed to using traditional transit metrics such as passengers per hour or cost per hour to measure the success of transportation services. These metrics do not capture the equity of service provision or frequency of service in underserved communities. For ADA paratransit service and wheelchair access on fixed-route buses, transit agencies typically look at metrics such as trip denials and total wheelchair boardings to measure the level of service success provided for persons with a physical disability. These measures account only for persons using a wheelchair or other mobility device. Most TNC/ridehailing services do not directly provide WAVs in their fleet, and those firms that provide WAVs themselves or through a third-party subcontractor do not have an established standard to measure equivalency of service (Moran et al. 2017). Some cities and states have begun mandating TNCs to provide WAVs as part of their fleets at no additional fare cost to the user; this requirement has helped improve access for persons with disabilities, although concerns of service equivalency remain (Yaffe 2020). The TNC Access for All Act in California requires TNCs to allow users to indicate whether they need a WAV for their trip as well as provide reports and plans to the state on how the company is doing in meeting accessibility targets; the act also established a fund to help add WAVs to TNC fleets (using a customer fee of $0.10 per trip) if companies demonstrate meeting accessibility targets (Grossman and Idziorek 2020).

Metrics for measuring the impact of new mobility can help cities and private companies understand how effective a program is, identify where improvements need to be made, and share success stories. McNeil et al.'s (2019) report on bikeshare systems included examples of data and metrics that can be used in new mobility options, such as user surveys, membership data, trip data, payment data, and station/location data.

Clewlow et al. (2018) discussed how cities can partner with shared mobility companies to evaluate progress of transportation equity with available data. The report states that a key metric in equity is the distribution of available vehicles—that is, measuring where vehicles are placed relative to predetermined zones representing underserved communities. The metric of distribution is distinctly different from vehicle utilization, which can also be tracked by zones to determine the effectiveness of vehicle deployments. A downside of predetermined zones is that they rely on specific geographic boundaries to determine service equity, yet many cities have disadvantaged populations throughout their boundaries. Cities must also assess the demographics of new mobility customers and persons not using the service (Clewlow et al. 2018).

Peterson et al. (2019) recommended focusing new mobility services on specific target objectives for equity, including defining user groups or neighborhoods and building the service (with involvement from those communities) to meet their needs. Cities should balance the needs of existing ridership while attracting new riders to services by using metrics that focus on transportation happiness or performance-based community engagement to improve access and should allow for flexibility to ensure broad participation (Shaheen et al. 2017).

Infrastructure for New Mobility Options

Infrastructure for new mobility includes facilities or technology assets that assist in the provision of vehicles and facilitate (or bar) access for underserved populations. For carshare and bikeshare options, there is associated infrastructure for vehicle parking and docked stations. Dockless bikeshare and scooter options may also have associated infrastructure, such as designated parking areas for vehicles to be staged for new customers that are free of sidewalk clutter. Curtailing clutter from micromobility vehicles particularly helps persons with disabilities and older adults successfully navigate sidewalks because it removes additional physical obstructions that impede access to transportation (Chen et al. 2020; Ruvolo 2021).

Infrastructure as a Hindrance to Access

Siting supportive infrastructure for new mobility options, such as docking stations, bike lanes, and designated pickup/drop-off areas, is critical in promoting the availability and adoption of service in low-income areas. Providing limited docking station sites in underserved areas likewise offers limited capacity for returning vehicles. Researchers found that the availability of bikeshare stations in Philadelphia and Chicago was correlated to income levels, with greater availability in higher-income areas (Niemeier and Qian 2018). Similarly, an analysis of CitiBike stations in New York City in 2019 found that the greatest proportion of bikeshare stations were in wealthier census tracts, with no significant changes in station distribution during the service's recent expansion (Babagoli et al. 2019). Micromobility companies with bikeshare and scootershare vehicles sometimes include equity considerations in station siting processes, but not all companies have explicitly included equity in their process (Shaheen et al. 2014). Additionally, equitable distribution of shared mobility vehicles and stations does not guarantee that underserved populations will use them (Chavis et al. 2018; Clewlow et al. 2018). For micromobility vehicles traveling in urban environments, protected bike lanes provide a safe and comfortable riding experience for customers. Investment in infrastructure for non-car modes of transportation is helpful for historically underserved populations to maintain access to needed mobility options during emergency events with reduced service availability from public transport and on-demand vehicles (Brown and Williams 2021).

Bike lanes provide a sense of security for micromobility users by limiting exposure to automobiles on roadways through separated bike paths or bike boxes at intersections (Ursaki and Aultman-Hall 2015). Goodman and Handy (2015) found that safety concerns due to poor bicycle infrastructure can be a barrier for low-income individuals to use bikeshare in their communities. Moreover, these communities often have fewer advocates for improvement of infrastructure, thus contributing to less investment and siting of lanes and stations than in more affluent areas (Howland et al. 2017). Addressing problems of a lack of or deteriorating infrastructure can help some user groups feel more comfortable using bikeshare and e-scooter share services (Reinhardt and Deakin 2020).

Local regulations on parking minimums or access to right-of-way can sometimes be outdated and discourage shared mobility operators (like those of carsharing and bikesharing systems)

from deploying their services in certain neighborhoods. Cities should look at these regulations and determine the right balance of need for application versus relaxing requirements to make services available for local residents (particularly traditionally underserved populations) (Martin et al. 2020).

Internet and cellular network access is a key component of transformational technologies in transportation. Limited internet availability and reliability in underserved communities, particularly rural areas, make it difficult for residents to access new mobility services, which require high-speed data connections for real-time data and location services for locating users and processing transactions. A study on autonomous and connected vehicles for rural, isolated, tribal, or indigenous (RITI) communities stated that major barriers to service equity include lack of communication infrastructure, lack of electrical power, high costs of expanding communication and power networks, and lack of local champions in the community to support these expansions (Sorour et al. 2022). Since new mobility services rely on mobile apps for customers to hail trips or unlock vehicles (Dias et al. 2017), the lack of internet or cellular coverage can limit the ability of users to access the service. This infrastructure can also provide better up-to-date travel planning information for users before they access the vehicle (Koeppel 2017). Kodransky and Lewenstein (2014) found that the requirement of internet access for participation in carshare service was less likely to be met by low-income persons. In 2016, the Pew Research Center found that 13% of adults in the United States did not use the internet, and lack of internet access was predominant among persons older than 65 with incomes below $30,000 who lived in rural areas (Shaheen et al. 2017).

Infrastructure-Specific Policies and Regulatory Strategies

No literature was found on specific policies or strategies being used to improve internet infrastructure in underserved areas. One solution to internet access issues for new mobility services is installing kiosks for users to unlock vehicles, make trip requests, and pay for fares and subscriptions. Kiosks have been used with docked bikeshare systems to allow users to pay for subscriptions under payment plans or for the cost of a single-day membership (Goodman and Handy 2015). However, these kiosks have the potential to provide better service in denser urban areas through better internet infrastructure and improved cellular coverage (Shaheen et al. 2017).

Another potential solution to limited internet availability is designing "lite" versions of smartphone applications that use less cellular data for essential processes and then download supplemental data once Wi-Fi is available (Shaheen et al. 2017). New mobility services can also use paper membership applications to enroll persons without smartphones. Ithaca CarShare allowed paper application processing through its Easy Access membership plan for persons without internet access (Kodransky and Lewenstein 2014).

Targeted siting of new mobility services and associated infrastructure in underserved areas requires measuring potential demand for service and incentives or subsidies (Kodransky and Lewenstein 2014; Shaheen et al. 2017). Transit agencies and government entities can also work with both private new mobility companies and community organizations to locate infrastructure in underserved neighborhoods. Los Angeles Metro conducted crowdsourcing efforts with community members to gather input on locating bikeshare stations, including distributing informational flyers and available phone numbers for providing feedback (McNeil et al. 2019).

Populus (2018) stated that the presence of micromobility companies can help cities gain increased public support for improved active transportation infrastructure. Shaheen et al. (2014) noted that bikeshare operators should work with city agencies to improve bicycle infrastructure that would generate additional users. Another issue for bicycle and scooter-share supportive infrastructure is that management of these systems is separated from city transportation

departments, yet these functions need to work in harmony to determine safe micromobility routes of travel and facilitate upgrades to infrastructure in needed areas (McNeil et al. 2019).

For AVs, there is a need to develop a standardized policy framework for AV/SAV design and deployment (Emory et al. 2022). Without standardized regulations, AV/SAV design, deployment, and networks can lack coordination. Some cities and states have already implemented their own AV/SAV frameworks, such as Portland, Oregon, which developed a framework (Fleets of Automated Vehicles that are Electric and Shared [FAVES]) that requires AVs to be electric and shared. Hawaii's AV policy framework (Accessible, Automated, Connected, Electric, and Shared [A2CES]) requires that AVs be electric, shared, accessible, and connected. Further, Minnesota DOT identified a set of goals and associated strategies to inform Minnesota state policy to require the accessible and equitable design and deployment of AVs/SAVs (Emory et al. 2022). The standardization of an AV/SAV framework informed by equity and accessibility goals will ensure that transportation-disadvantaged populations are included in the design and deployment of AVs/SAVs.

Elements of Successful Business Models

Business models of shared mobility systems require improvements in structure and public agency coordination to ensure quality infrastructure in underserved communities. Shared mobility companies focus their services in areas with the highest demand, meaning they are unlikely to target low-income communities. A better understanding of regulations and incentives to improve access to services can improve the sustainability of shared mobility business models (Kodransky and Lewenstein 2014). Public agencies must understand the value proposition of for-profit companies to provide service in underserved communities, including subsidies needed and efforts of businesses to reach these populations. Including a mix of partners from public, nonprofit, and for-profit sectors is a mechanism for expanding new mobility services to low-income communities since public and nonprofit entities can help identify barriers and alternative revenue sources, thereby enabling private companies to scale up service in these communities (Kodransky and Lewenstein 2014).

Shaheen et al. (2017) found that equity outcomes in shared mobility business models were difficult to assess, particularly in cases where private operators received monetary support from agencies with federal funding as part of pilot partnerships. Subsidies from federal funding may not be a substitute for removing existing financial barriers in shared mobility business models but instead may function to help subsidize operational expenses. Eventually, some shared mobility business models for ridesharing/ridesourcing services will adjust to AVs instead of available drivers.

Shared mobility business model advantages in providing service in underserved communities include flexibility in filling current coverage gaps, service in late-night and off-peak periods, lower upfront costs to users, tailored services to specific physical and cognitive disabilities, and flexible payment and access options (Shaheen et al. 2017). New mobility services can also make access to systems for low-income and disadvantaged users more like public transit models, with specific access mechanisms for these user groups. Healthy Ride in Pittsburgh is an example of a bikeshare system that developed a pricing model that complements public transit pricing (McNeil et al. 2019).

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Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GHSA	Governors Highway Safety Association
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S. DOT	United States Department of Transportation

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