NITC
NATIONAL INSTITUTE for TRANSPORTATION and COMMUNITIES

NITC Research Roadmap
Lit Review
June 2022

Photo by Cait McCusker

A Decade of Research in New Mobility and Technology

NITC Research Roadmap: Lit Review

Becky Steckler, University of Oregon
Sadie Mae Palmatier, University of Oregon
Kelly Clifton, Portland State University
Stephen Fickas, University of Oregon
Pengei Taylor Li, University of Texas, Arlington
Xianfeng Terry Yang, University of Utah
Mahmut Yasar, University of Texas, Arlington

Portland State University | University of Oregon | Oregon TECH | The University of Utah | The University of Arizona | University of Texas Arlington

What follows is an ***excerpt*** ***from the full report "NITC Research Roadmap: New Mobility and Technology"*** *which serves as internal guidance to where our focus on research and workforce development should be applied next in this area. It is one in a series of six reports looking at:*

Transportation and Land Use

Multimodal Data and Modeling

Walking and Bicycling

New Mobility and Technology

Transportation Equity

Transportation Resiliency

These excerpts provide a lookback of the last decade of projects funded by the National Institute for Transportation and Communities, a U.S. DOT University Transportation Center. Through these literature reviews we hope you'll gain new transportation insights that our researchers and partners have shared.

Learn more about the impact of our research here:
https://nitc.trec.pdx.edu/nitc-research-areas

NITC
NATIONAL INSTITUTE for TRANSPORTATION and COMMUNITIES

NITC Research Roadmap: New Mobility and Technology
Lit Review

The Authors

Becky Steckler, University of Oregon (0000-0002-4253-7215)
Sadie Mae Palmatier, University of Oregon (0000-0001-9710-3839)

National Institute for Transportation and Communities

The National Institute for Transportation and Communities (NITC) is one of seven U.S. Department of Transportation national university transportation centers. NITC is a program of the Transportation Research and Education Center (TREC) at Portland State University. This PSU-led research partnership also includes the Oregon Institute of Technology, University of Arizona, University of Oregon, University of Texas at Arlington and University of Utah. We pursue our theme — improving mobility of people and goods to build strong communities — through research, education and technology transfer. **Learn more at https://nitc.trec.pdx.edu/**

Recommended Citation
Steckler, Becky, Palmatier, Sadie Mae. NITC Research Roadmap: New Mobility and Technology. NITC-RR-1539. Portland, OR: Transportation Research and Education Center (TREC), 2022.

Table of Contents

Acknowledgements

This project was funded by the National Institute for Transportation and Communities (NITC; grant number 1539), a U.S. DOT University Transportation Center.

This report relied on the guidance and support of the New Mobility and Technology Advisory Team. Thank you.

- Kelly Clifton, Portland State University
- Stephen Fickas, University of Oregon
- Pengei Taylor Li, University of Texas, Arlington
- Becky Steckler, University of Oregon
- Xianfeng Terry Yang, University of Utah
- Mahmut Yasar, University of Texas, Arlington

This Roadmap was written primarily by Becky Steckler, AICP, Program Director, and Sadie Mae Palmatier, Graduate Employee, from the Urbanism Next Center at the University of Oregon.

The Technology and New Mobility Advisory Team would like to thank the following people for attending the December 2021 Workshop and providing their expertise to this report:

- Thomas Bamonte, North Central Texas Council of Governments
- Tosh Chambers, Move PGH
- Evan Costagliola, Nelson\Nygaard
- Nico Larco, University of Oregon
- Aziz Rahman, City of Fort Worth
- Robert Sheehan, U.S. Department of Transportation
- Jacob Sherman, Portland Bureau of Transportation
- Alison Tanaka, Portland Bureau of Transportation
- Calvin Thigpen, Lime
- Shin-pei Tsay, Uber
- Eric Womeldorff, Fehr and Peers

Overview

Over the past 20 years, advances in computer, cellular, and remote sensing technologies have presented new and expanding opportunities for the mobility of people and goods. The widespread adoption of smartphones, growing from 35% in 2011 to 85% in 2021 (Pew Research Center et al., 2021) and increased ownership and presence of personal computers and other devices in the home, 51% of households in 2000 to 92% in 2018 (Martin, 2021) has increased mobility options. The development of shared platforms and new vehicles and devices including e-scooters, bikeshare, transportation network companies (TNCs), carshare, and microtransit to online shopping and access to goods and food shipped directly to households and businesses have increased mobility and accessibility. Smart city technologies[1] (Thales Group, 2021) and vast improvements in sensors that allow for real-time data collection and decision-making is also presenting new opportunities to increase efficiency, safety, and operational performance while potentially reducing congestion and energy use, among other applications. Given the relative nascency of these technologies; constant and rapid evolution of the technology itself; and increased application and deployment, academics and the public and private sectors still have much to learn about the opportunities and challenges of these emerging technologies on the creation of sustainable, livable, and equitable communities.

The **National Institute for Transportation and Communities (NITC)** has worked to address some of the research gaps in technology and new mobility since its inception in 2012. Now, it is assessing the cumulative body of NITC-funded research to help develop an agenda for the future. In addition, NITC leaders want to identify workforce development needs to meet the most important challenges facing transportation agencies and policymakers related to technology and new mobility. The purpose of this document, the Technology and New Mobility Roadmap, is to:

- Define the scope of technology and new mobility addressed in this report and define the questions being addressed.
- Describe the research topics and findings NITC-supported researchers have started or completed (with and without NITC funding) related to technology and new mobility primarily, as well as other University Transportation Centers (UTCs) research on these topics, secondarily. This research summary will help identify major themes related to the social and political questions the researchers were trying to answer.
- Identify research gaps to advance practice and policy and make recommendations on how NITC-supported research can fill these gaps.
- Describe the workforce needs for new mobility and technology jobs, and make recommendations for how NITC universities can provide the needed skills and education to students.

[1] From Thales Group "A smart city is a framework, predominantly composed of Information and Communication Technologies (ICT), to develop, deploy, and promote sustainable development practices to address growing urbanization challenges."

Scope of the research

This report provides a summary of NITC-funded and other research related to new mobility and technology. For the purposes of this report, we included research related to new mobility devices, services and technologies as shown in Table 1 (below) and defined in detail in Appendix A. New mobility topics include common vehicles, devices, and the associated services. While carsharing and microtransit are generally included in new mobility services, there was very little NITC-funded research related to these topics, thus there was no information to report. Technology was defined broadly to encompass a wide range of applications, such as e-commerce, transportation planning and pricing, to Intelligent Transportation Systems (ITS) that collect data or communicate digitally between devices, vehicles, and infrastructure with the ability to make real-time changes to the operating environment.

Table 1. New Mobility and Technology

New mobility vehicles, devices, and services	Micromobility – shared bikes and e-scooters
	Carsharing
	Transportation network companies
	Microtransit
	Autonomous vehicles (passenger and goods, on-street)
	Drones (sidewalk and aerial, smaller, primarily off-street)
Technology	E-commerce and urban delivery
	Planning and pricing (such as Mobility as a Service)
	Smart city technologies (such as V(ehicle)2V; V2I(nfrastructure); T(echnology)2I – wearable technology/connected pedestrians connected to infrastructure; and T2V – wearable technology/connected pedestrians connected to vehicles

Note: While carsharing and microtransit are generally included in new mobility services, there was very little NITC-funded research related to these topics.

Methods

Documenting the current NITC research involved three stages. First, the body of research available online on NITC.trec.pdx.edu was reviewed (see Appendix B for a full list of research). Then the research was categorized into subsections organized by themes identified in the literature. These themes are:

- Equity
- Health and Safety
- Environmental Impact
- Policy Issues
- System Management
- Operational/Pilots

A similar process was repeated for research conducted by previously funded NITC researchers that was not funded by NITC grants. The full list of NITC researchers who were considered in this study are listed in Appendix C. This research was pulled from Google Scholar. Finally, authors conducted a third, preliminary (not comprehensive) scan of research of new mobility and technology topics by researchers of non-NITC University Transportation Centers using the TRID database.

The conversations with public- and private-sector professionals was organized and facilitated by the NITC roadmap team. We recruited transportation professionals who focus on the development of new mobility services and deployment of services and technology. We were interested in understanding how professionals in the field are thinking about the future integration of these technologies. In addition, we asked what expertise future professionals would require to be effective in shepherding or navigating the transition to these new mobility and technology forms.

What do we know about new mobility and technology?

This section summarizes existing new mobility and technology research. First, we categorized the existing NITC-funded research by topic according to themes in the literature. These themes include equity, health and safety, economic impacts, environmental impacts, system management, and operational pilots. We then explored complementary research by NITC-supported researchers at NITC universities, as well as scanned similar themed research at other UTCs.

Research funded by NITC or conducted by NITC-supported researchers include a few key themes:

New Mobility Vehicles, Devices, and Services

- **Impacts on equitable mobility.** Research related to equitable mobility dominates the micromobility and TNC studies funded by NITC or conducted by NITC-supported researchers. Much of the research explores how to increase participation, reduce barriers, and design shared systems that are used by all residents and visitors. Studies also explore opportunities and barriers of adaptive use (bikeshare) and consideration for AV services among older adults.

- **Impacts on health and safety.** NITC researchers have examined the safety of e-scooters, and safety considerations of interactions between micromobility modes as well as demographic and location considerations. One study also considered the impact of e-scooters on activity levels and the prevalence of chronic disease. NITC funds have also been used to study e-scooter parking and the safety issues related to e-scooters that potentially block sidewalks and curb cuts.

- **Implications for public policy.** Besides research related to equity policies, there is a body of research funded by NITC or conducted by NITC-supported researchers that explores themes around models of governance and policy approaches and frameworks for the deployment of new mobility pilot projects. There is a body of knowledge related to assessments and evaluations of pilot projects for new mobility generally and micromobility and autonomous vehicles specifically. NITC-funded projects consider implications for policy and model language for regulations. In addition, researchers are considering the fiscal implications of some of these services, primarily AVs (that are shared and electric).

Transportation Technology

- **Implications for transportation system management.** The vast majority of the smart city technology research focuses on making the transportation system more efficient and increasing traffic flow and safety. Research includes multiple modes, including transit, bikes, and automobiles. Researchers are also exploring highway performance with connected autonomous vehicles (CAVs) and the intersection with human-driven vehicles.

- **Improvement on traffic safety.** Much of the research on improving transportation system management includes safety as well as throughput. The safety focus is not only on vehicle crashes, but also reducing crashes with pedestrians and bicyclists.
- **Prioritization on active transportation.** NITC-supported smart city research focuses on some of the most vulnerable road users, such as those who depend on curb ramps, as well as how to improve the transportation system for pedestrians, bicyclists, and transit riders. Several researchers are actively researching connected technology that will prioritize bicyclists and improve safety for these vulnerable users.

New Mobility Vehicles, Devices and Services Research

Micromobility is one of the most common new mobility topics of study for NITC-funded research and non-NITC-funded research. Within micromobility, most studies have dealt with questions of equity. To date, there has been little to no research on carshare or microtransit. Non-NITC-funded research and other UTCs have focused their research on drones, AVs, and TNCs more than NITC.[2]

Micromobility: Bike Share

Equity

NITC Funded: Bikeshare is one of the most commonly explored research topics by researchers with NITC funding. This is understandable given that bikeshare is one of the longest existing new mobility services. NITC research in this area has primarily focused on answering the following questions:

1. What are the strategies to increase participation among lower-income groups and people of color? (MacArthur, McNeil, & Broach, 2020; McNeil, Dill, MacArthur, & Broach, 2017; Howland et al., 2017)
2. What is the geographic spread of bikeshare in a community and how can systems be redesigned to reduce barriers to bikeshare access? (McNeil et al., 2017)

[2] In each section we will describe research that has been funded by NITC (NITC-F), the research that has been conducted by NITC researchers but not funded by NITC (NITC-NF), and the research that has been conducted by other UTCs (Other-UTC). All NITC-NF research has been completed while NITC and Other-UTC research may be in progress. When this occurs, it will be noted.

3. What is the response to these strategies from bikeshare users, residents, and operators? (McNeil, Dill, MacArthur, & Broach, 2017)
4. How can the interface of bikeshare systems be designed to better serve all users? (Germany & Sperranza, 2014)

The research surrounding bikeshare equity involved data from three dense, older cities and from neighborhoods with primarily African American populations (MacArthur, McNeil, & Broach, 2020). There has been little research in other cities with a more sprawling and less compact urban form or with different demographic groups.

NITC-NF: Similar to NITC-F research, bikeshare equity is a central question and research topic in the literature from NITC-NF projects. Past research has examined racial and socio-economic disparities in shared vehicle use for both bikes and cars (Dill & McNeil, 2021), and how cities and bikeshare operators are attempting to improve access and equity in their bikeshare programs (McNeil et al., 2020). Beyond income levels, other equity research has examined efforts to increase adaptive bikeshare use. These programs specifically target aging adults and those with mobility challenges (MacArthur, McNeil, Cummings, et al., 2020). Overall, more research is necessary to determine how to address barriers to bikeshare, but particularly for addressing barriers to carshare and where these barriers may experience overlap (Dill & McNeil, 2021).

Other UTCs: UTC bikeshare equity research in progress will explore multiple topics including whether dockless or dock-based bikeshare systems provide more access for disadvantaged communities (Jaller & Niemeier, 2022). Other research includes exploring how to use bikeshare to connect affordable housing with transit services (Jaller & Xiaodong, 2022). Completed research examines how to prioritize bikeshare to improve underserved communities' access to jobs and essential services (Niemeier & Xiaodang, 2018), and document bikeshare access across the country (Ursaki & Aultman-Hall, 2015).

Economic

Other UTCs: Prior UTC research has examined the economic benefits of capital bikeshare in D.C. (Buehler & Hamre, 2014).

Policy and Regulation

NITC-NF: Steckler et al. (2020) assessed over 220 new mobility and urban delivery pilot projects in the United States and Canada and conducted 11 case studies to catalog lessons learned, emerging trends and considerations and promising practices. The most common type of pilot project included in this study was micromobility.

Other UTCs: Bikeshare research by other UTCs has covered many topics of policy and regulation including a review of micromobility laws (Pimentel et al., 2020), and the effects of land use decisions on bikeshare and other sustainable transport modes (Mondschein, 2015).

System Management

Other UTCs: Other UTC research has explored system management work such as how to improve the system operations of bike shares (Paleti et Al., 2018); how to model their integration with other transportations modes (Ravishanker & Konduri, 2019); and what role infrastructure plays in their adoption (Azimi et al., 2021).

Micromobility: E-scooters

The e-scooter research funded by NITC and conducted by NITC researchers has explored the impacts of combining e-scooters with other forms of micromobility in terms of equity considerations and vehicle miles traveled (VMT). This research also explores the impacts of e-scooters on the health and safety of users, and the policy and regulation implications of e-scooter adoption, especially in regard to parking. UTC research has focused on the environmental and equity implications of e-scooters. Virginia Tech has conducted a large share of other UTC e-scooter research.

Equity

NITC-Funded (in progress): NITC researchers are currently exploring how e-scooters can be used in conjunction with other forms of micromobility, such as a bikeshare membership or transit passes, to improve access for low-income residents (Tan et al., 2021). Similarly, researchers are examining how these mobility forms can be used in conjunction with carshare and other ride-hail services to access opportunity and complete errands. Other research concerns examining the equity requirements of shared-mobility programs and evaluating how effective these programs are at increasing adoption among target populations. This work directly builds off of McNeil et al.'s (2019) work to broaden the scope to carshare and e-scooter programs (Brown & Howell, 2021).

Health and Safety

NITC-Funded (in progress): Safety is a major concern when examining current and future e-scooter adoption in cities. Specifically, how safe e-scooters are; how micromobility options interact with each other; how safe these interactions are; and if they are not safe, whether there are specific demographic characteristics or geographic locations that experience these unsafe behaviors and interactions (Currans et al., 2021). On the level of personal health, researchers are exploring how e-scooters are changing mode choice for individuals, which is affecting the activity levels of residents and, by extension, the prevalence of chronic disease in a community. This body of research aims to inform long-term decisions about the impacts of e-scooters on public health (Iroz-Elardo, 2021).

NITC-NF: The completed research on e-scooters from NITC researchers also largely concerns questions of health and safety. A review of existing e-scooter literature documented the types of injuries most commonly associated with e-scooters (head injuries and fractures) and the most common type of injured e-scooter users (30-year-old males). These findings do not compare injury levels with bicycling, an area of research which requires further examination (Iroz-Elardo & Currans, 2021).

Other-UTC: UTC research will explore the health and safety of e-scooters from numerous angles. Forthcoming research will explore the impacts of speed on dockless e-scooter crashes (Machemehl, 2023). Other research has explored e-scooters' interactions with other street users (Klauer, 2022) and pedestrians (Ipek, 2023).

Policy and Regulations

NITC-Funded: The introduction of e-scooters into cities has prompted research on the policy and regulation of these devices into existing transportation ecosystems. A forthcoming review of e-scooter adoption in Portland, OR, during their second pilot program will examine the change in VMT since adoption. Researchers will analyze the charging operations of e-scooter companies in the metro region and the mode shift of individuals using the e-scooters. Results from this study aim to estimate the impacts of different company operations and how cities can minimize negative impacts (MacArthur & Dill, 2021).

NITC-NF: E-scooter parking is a concern in cities. E-scooters are sometimes improperly parked and crowd sidewalks, posing safety hazards. However, improperly parked vehicles (specifically ride-hail and food delivery drivers) can impede access more often than bikes and e-scooters (Brown et al., 2020). To combat the e-scooter parking issues, cities can employ parking regulations on users and operators to reduce the levels of conflict while still achieving sustainable transportation goals (Brown, 2021).

Other-UTC: E-scooter policy research has examined how to successfully deploy e-scooters on college campuses (Mollenhauer, 2021), and what the policy implications of e-scooter adoption are in cities (Zhang & Guo, 2020).

System Management

NITC-Funded (in progress): Forthcoming research will use data-driven optimization models and efficient computation methods with solution quality guarantees to help solve e-scooter sharing system and operation problems. These changes will help ensure system reliability and cost effectiveness (Cheng, 2022).

Environmental

NITC-NF: A review of existing literature on micromobility examined how micromobility modes are replacing automobile, walking, and transit trips, resulting in net-negative GHG emissions (McQueen et al., 2021).

Other-UTC: UTC research has examined the environmental impacts of e-scooter adoption through congestion reduction (Xilei, 2020) and a reduction in VMT (Harper & Fan, 2021).

Carshare

There is only one existing non-NITC-funded study explicitly about carshare. Given the relatively low amount of research, this could be an area of further exploration, but further review is necessary. There are few UTC reports on carshare, mostly about equity.

Equity

NITC-NF: Peer-to-peer car share doesn't appear to change the car owners' travel behavior much, but can have equity implications. These carshare systems can support no- or low-car households and low-income households in completing trips they otherwise would not have been able to make (Dill et al., 2019).

Other-UTC: Research from UTCs has explored how carshare can provide transportation access to low-income residents (Hyun et al., 2019), and how it can be integrated with transit oriented development (Chapple, 2013).

Microtransit

There are currently no NITC-funded research projects about microtransit. The existing studies have come out of other UTCs. Most microtransit studies are exploring operational elements of deployment for both AV and non-AV deployments vehicles, such as the necessary infrastructure; electronic planning and ticketing; and marketing and behavior changes.

Operational/Pilots

Other-UTC (in progress): One study is examining the impacts of an AV-based microtransit development in Florida (Peng, 2021). Other research will explore how transit agencies are marketing new on-demand services to increase customer education and service utilization (Garcia-Colberg, 2021). A forthcoming report about a microtransit pilot program in the Sacramento Regional Transit District will explore the impacts of this service on the consumer market, environmental benefits, cost efficiency, and demand for such a service (Xing & Pike, 2021). Another study is developing a model to allow cities to construct a microtransit portfolio that will fit their individual residents' needs (Chow, 2020).

Environmental

Other-UTC: Microtransit can be useful to address first mile/last mile problems associated with public transit. These services offer an affordable transportation alternative to reduce traffic congestion and provide access to employment, health, education, and other services, increasing the livability of a region (Cavellos, 2020). However, transit operators must ensure that these services are complementary to existing transit instead of competition (Kortum & National Academies of Sciences, Engineering, and Medicine, 2021).

Transportation Network Companies

Research on TNCs by NITC researchers has largely been conducted with non-NITC funding. This body of research is focused primarily on equity implications of TNCs in Los Angeles, CA, and changes to the city's parking revenue due to TNC adoption. There is only one NITC study on TNCs.

Equity

NITC-Funded: NITC research on TNCs found that ride-hailing currently fills a transportation gap for nonprofits that provide services to communities. However, the use of TNCs is costly both in time and money and doesn't service all communities, making the geographical benefit unequal. This research recommended nonprofits provide their own TNC services or receive subsidies to continue using TNCs. This research only looked at one geographic area (Seattle, WA) and is not representative of the nation (Mason, 2021).

NITC-NF: Ride-hailing services provided by TNCs have been shown to operate with less racial discrimination than taxi services. However, discrimination still occurs when drivers learn of rider characteristics (Brown, 2019). Equity consideration became increasingly important under COVID-19 as areas with older and minority residents continued to rely on TNC trips to attain essential services more than higher-income areas (Brown & Williams, 2021). Additional research has examined the relationship between access to transit and socio-economic status on the use of TNCs (Barajas & Brown, 2021). Cities have begun to regulate TNCs using ride feeds which can have significant equity implications. While there are tactics to reduce cost burdens, in low-income areas these structures can be regressive when considering income (Brown, 2021).

Other-UTC (in progress): UTC research will explore how TNC systems can better serve marginalized populations (Shaheen & Ipek, 2022); how to determine who uses TNCs across a megaregion (Jiao et al., 2019); and whether these trips could be better served by public transit services (Pande & Barbeau, 2021).

Environmental

NITC-NF: Skov et al. (2020) considers how ride-hailing differs from other vehicles and should be considered a separate source of emissions in urban areas. The authors then examine three different methodologies to quantify GHG emissions from ride-hailing.

Policy and Regulation

NITC-NF: TNC and ride-hail travel have had significant impacts on parking in cities. Using Uber and Lyft data from Seattle (Clark and Brown, 2021), examined how ride-hailing services affect parking behavior and VMT. This research suggests at a certain point of ride-hail use, parking occupancy in an area may begin to decline, prompting flexible and adaptable parking policies from cities.

Other-UTC (in progress): Forthcoming UTC research is examining how to increase rideshare pooling as a form of curb management and how marginalized populations use TNCs for their essential travel needs (Shaheen et al., 2022; Shaheen & Ipek, 2022). Other researchers are exploring how to promote electric vehicle adoption among TNC drivers (Sanguinetti et al., 2022).

Autonomous Vehicles

Autonomous vehicles are likely to share a wide range of characteristics with existing vehicle uses as well as utilizing technology in new and unique ways. AVs may be individually owned and replace human-driven passenger vehicles and trucks, as well as replace human-driven commercial trucks. They will likely be used as fleets of shared services like taxis and TNCs, as well as microtransit and other transit modes. In addition, they will make street, sidewalk, and air deliveries of goods and food. They will likely also be connected to other vehicles, infrastructure, and devices with the ability to route and park based on existing demand and supply.

Environmental

NITC-Funded (in progress): While the technology is still being developed, many cities are anticipating AV services in the future and researchers are studying the potential impacts. One study of this new mode of transport is trying to determine how it might affect VMT within cities (Wang & Wu, 2020) and urban form (Schlossberg & Brinton, 2019).

System Management

NITC-Funded (in progress): The work of Wang and Wu (2020) will provide an open-source software tool to help metropolitan planning organizations (MPOs) simulate different scenarios of AV adoption, and identify policy responses that would ensure sustainable and equitable travel and land use. Similarly, Schlossberg and Brinton seek to develop a set of model policies and codes that cities can use to adapt to various stages of AV deployment to align transportation outcomes with city goals (Schlossberg & Brinton, 2019; Wang & Wu, 2020).

NITC-NF: A team of researchers at the University of Oregon and the Urbanism Next Center conducted a literature review analyzing the impacts of emerging forms of mobility and technology on cities (Howell et al., 2020). Responding to such changes may be aided by the integration of AVs into the Regional Strategic Planning Model (RSPM) tool, which can help cities make more informed decisions about future scenarios (Wang et al., 2018).

Other-UTC: Other UTCs are exploring a wide range of issues related to the development of AVs and deployment of AV services. Many of the UTCs focus on the development of the systems that need to be created for the safe operation of and interaction with AVs, including the Mobility 21 UTC that includes Carnegie Mellon University and the University of Pennsylvania, The Center for Advanced Multimodal Solutions and Education and University of South Carolina.

Policy and Regulation

NITC-Funded: Prior research has examined how the adoption of AVs is changing both mobility and e-commerce deliveries and how cities can adopt a new mobility strategy in response to these changes (Steckler & Lewis, 2019). Further research has examined the potential fiscal impacts of AVs on cities through the proxy study of TNCs, and suggested regulatory changes to mitigate these impacts (Clark, 2019).

NITC-NF: The adoption of AVs within cities is expected to drastically shift municipal finance. By examining five Oregon cities, Lewis and Clark (2021) predict that transportation revenues (from parking dues, fuel taxes, citations, etc.) may decline in an autonomous, electric, and shared future. To combat these declines, cities should monitor trends and develop new revenue sources. These declines will likely vary by community. Instead, flexible policies that respond quickly to on-the-ground changes are advisable (Clark & Brown, 2020).

Environmental

NITC-NF: For cities that are attempting to reduce transportation-related emissions, AVs may operate similarly to TNCs by contributing to increases in VMT and congestion, and decreases in transit use and non-vehicular modes (Larco et al., 2018). Alexander et. al (2021) suggests the use of climate action plans to ensure that AVs reduce rather than increase GHG emissions. Such provisions could include encouraging TNCs to invest in electric vehicles, creating programs that incentivize shared rides, and integrating multiple forms of transit through Mobility as a Service (MaaS) app development (Alexander et al., 2021).

Drones

While Urbanism Next at the University of Oregon anticipates it will publish an assessment of four personal delivery device (PDDs) pilot projects in four communities across the U.S. in 2022 (NITC-NF), existing research on drones has been exclusively conducted with non-NITC funding by Miguel Figliozzi at Portland State University. His research explores the environmental impacts of drones. UTC research on drones is robust. This literature has explored using drones for transportation systems monitoring and assessment for drone urban parcel delivery.

Environmental

NITC-NF: Unmanned Aerial Vehicles (UAVs) or drones are more CO_2e efficient on a per-distance basis at delivering small payloads than conventional vehicles. However, if a few customers can be grouped into a route, tricycle and electric van delivery services are more CO_2e efficient than UAVs (M. A. Figliozzi, 2017; M. Figliozzi & Jennings, 2020). Sidewalk autonomous delivery robots, road autonomous delivery robots, and UAVs can be more efficient than e-vans and conventional vehicles under certain circumstances; however, they may not necessarily reduce on-road travel and may create large changes in the labor market (Figliozzi, 2020). Considering these changes is of increasing importance as the COVID-19 pandemic has spurred some public acceptance of their use (Pani et al., 2020).

System Management

Other UTC: UTCs such as the Pacific Northwest Transportation Consortium and Mountain-Plains Consortium have been exploring the use of drones to monitor infrastructure such as roads and bridges and improve traffic safety. Other UTC research recently completed or still in progress will explore the costs and benefits and appropriate management of parcel delivery using drones (Hansen et al., 2021; Jaller, 2022; C. Liu, 2022).

Transportation Technology

NITC-funded research on new transportation technology explores how to improve the design and operations of intelligent transportation systems. Some of this work has involved the creation or improvement of new technology while others have explored the implications of its use. Research with non-NITC funding has explored the impacts of e-commerce on cities while other UTCs have researched MaaS pricing.

E-commerce

Forthcoming NITC-funded research will examine COVID-19's impact on e-commerce in cities. Non-NITC-funded research has explored the impacts of e-commerce on cities related to municipal finance and environmental benefits.

Economic

NITC-Funded (in progress): A forthcoming study will examine how the COVID-19 pandemic has changed shopping habits among American consumers. This research will provide insight into emergency food aid and the interplay between e-commerce and retail services (Currans & Howell, 2022).

NITC-NF: E-commerce is expected to change land valuation for existing brick and mortar stores, thereby shifting property tax revenues and development patterns. This will impact cities that are highly dependent on commercial property tax revenue and/or sales tax (Clark et al., 2017). Steckler et al. (2020) explored how cities have used pilot projects as a tool to mitigate negative impacts from e-commerce. The adoption of electric trucks in e-commerce may also impact cities. However, adoption of these vehicles is dictated by several factors dictating their competitiveness in comparison to conventional diesel trucks (Davis & Figliozzi, 2013; Feng & Figliozzi, 2012). E-commerce and urban delivery are increasing demand at the curb and researchers are exploring dynamic curbside management (in progress, Urbanism Next is working with the Fehr & Peers team) (Fehr & Peers, 2022).

Other-UTC: One of the chokepoints for e-commerce and urban delivery is the need for limited space at the curb to make deliveries. Researchers at other UTCs are conducting research on curb management strategies and data collection (including for parking), and evaluated the performance in the downtown area of San Francisco (Jaller et al., 2021).

Environmental

NITC-NF: The environmental impacts of e-commerce will include travel-related emissions (Figliozzi, 2011) and the recycling of shipping packaging and materials, which may also strain recycling systems and waste collection (Clark et al., 2017).

Planning and Pricing

Mobility as a Service

Existing research on MaaS and transportation wallets is still in progress from other UTCs and non-NITC funding. This research has focused on how these pricing tools will change travel behavior.

System Management

Other-UTC (in progress): Future research will monitor changes in the use of shared mobility, AVs and MaaS to determine how these services could expand travel options, how they shift reliance from private vehicles, and how MaaS options dictate attitudes towards automation and shared mobility (Circella & Alemi, 2021). Additional research will focus on creating a MaaS user preference structure (Lee et al., 2022) and aiding transit agencies in their transit network design (Lee, 2022). Additional research will examine how the combination of MaaS data with AVs or connected AVs will lower the cost of MaaS and impact VMT (X. C. Liu, 2020).

Existing literature has reviewed which key stakeholders must cooperate extensively in order for MaaS projects to be successful (Hensher et al., 2020). A MaaS trial in Sydney explored changes to travel behavior and a reduction in VMT (Arias-Molinares & García-Palomares, 2020).

Operational/Pilots

NITC-NF: A Portland, OR, based Transportation Wallet program for residents of affordable housing will explore how this program can increase access and help familiarize low-income residents with new mobility services (Tan et al., 2021). Nico Larco conducted research for TNO, a European organization, on governance models of MaaS. The research included six international MaaS case studies (TNO, 2020).

Smart City Technology

NITC-funded research on smart city technology has explored how to improve transportation systems through improved signals, sensing, and travel time predictions. Much of this research involves connected vehicles, infrastructure, and technology in various degrees, and is designed to improve the transportation system and model how to effectively integrate connected vehicles, technology, and infrastructure into existing transportation networks.

Equity

NITC- Funded: GeoAI methods such as open street map, LiDAR, and aerial imagery can be used to fill in missing curb ramp data to help those with limited mobility navigate around urban spaces (Deitz, 2021).

System Management

NITC-Funded: Smart cities research has involved reconfiguring existing transportation signals to increase traffic flow and safety and estimate pedestrian delay without the need for additional resources (Karimpour et al., 2020, 2021). Using high-resolution bus detection data can also improve travel time prediction and help identify congestion in a transit system (Stoll et al., 2016). Other forms of ITS can help achieve energy reduction goals by reducing VMT (Jordan et al., 2014).

Fickas (2021) focused on improving flow for bicyclists on a bike corridor with fixed-time signals. Using a cellphone-based app, this project attempted to improve a machine-learning algorithm that seeks to eventually give bicyclists real-time information on whether to slow down, speed up, or maintain speed to make a green light.

Tufte et al. (2021-in progress) is conducting research in Portland to understand how connected vehicles and connected infrastructure can improve safety and efficiency of the transportation network. The research will study how to incorporate pedestrians and bicyclists into CV applications.

Recent research has worked to improve vehicle-to-vehicle (V2V) technology with simulations of highway performance under different levels of connected autonomous vehicles (CAVs) integration with existing transportation networks dominated by human-driven vehicles (HVs) (Yang et al., 2018). Most V2V research focuses on automobiles, however connected bicycles may reduce barriers to bicycle mode share and better accommodate cyclists (MacArthur et al., 2019).

NITC-NF: The research on V2V technology has involved creating a system that increases urban arterial safety and mobility (Yang et al., 2019) and adaptability under different rates of connected vehicle (CV) penetration in a mixed CV and HV transportation system (Yang et al., 2019), and optimizing performance of CVs on highways and how speed changes impact the traffic state (An et al., 2019).

A study by Yang et al. (2019) explored how CV technology can be integrated with smart traffic controls, dynamic traffic signal coordination, and transit signal priority for connected buses to support the operation of urban signalized arterials with CVs, reducing accidents, harmonizing speeds, and reducing communication delays.

Other-UTC: UTC research has explored how to coordinate CVs to result in more fuel-efficient platooning (Lakshmanan, 2021), and how to improve sensing and communication between these devices for more efficient transportation networks (Ban & Li, 2018). Similarly, other UTC research has explored using simulations to study CV adoption (Ishak et al., 2016), and how to improve overall CV efficiency and safety in adverse road conditions (Akin et al., 2018).

Research from the Center for Connected and Automated Transportation (CCAT) has explored many topics related to V2I including how to integrate CAVs with infrastructure communication to reduce crashes (Pradhan et al., 2020). Other research has explored how to improve the functionality of V2I communication at signalized intersections (Rakha et al., 2016). Researchers from Carnegie Mellon have developed an algorithm for use in smart parking information systems (Hampshire et al., 2014).

Research from Mobility21 UTC, headed by Carnegie Mellon University, has explored smart city system management through the lenses of cost-effective designs (Peha et. al, 2020), right-of-way permitting systems (Qian, 2021), and city-wide sensing for ride distribution (Zhang et. al, 2019).

Operational/Pilots

NITC-Funded (in progress): Forthcoming research from Tufte et al. (2021) will examine how the application of connected vehicle technology (CV) can help transportation planners better understand connected streetcar performance and prioritize modes of travel.

Environmental

NITC-NF: A study from Huang et al. (2018) sought to create a fuel-efficient driving system for CAVs.

Policy and Regulations

Other-UTC: Smart city technology research from other UTCs includes frameworks for integrating transportation into smart cities (Shaheen et al., 2019), and using smart city technologies to solve first mile/last mile challenges in cities (Gelbal et al., 2020).

Conclusions

New mobility and technology topics are an emerging and growing area of research for NITC-supported researchers as well as researchers at UTCs across the country. New mobility services and technology were evolving before the COVID-19 pandemic disrupted mobility in March 2020. As people and service providers adapt to the pandemic, mobility services will continue to evolve. In addition, funding from the recently passed federal infrastructure spending bill allows local, state, and federal governments to invest in connected infrastructure technology that will change how public agencies manage transportation systems. NITC is uniquely positioned to research these changes and communicate how these changes could impact communities.

References

Akin, Mi., He, Y., & Shi, X. (2018). *The Use of Connected Vehicle Technology to Facilitate Multimodal Winter Travel (Phase I)* (2017 Project 09). Center for Advanced Multimodal Mobility Solutions and Education (CAMMSE @ UNC Charlotte) The University of North Carolina at Charlotte. https://cammse.charlotte.edu/sites/cammse.charlotte.edu/files/media/CAMMSE-UNCC-2017-UTC-Project-Report-09-Shi-Final.pdf

Alexander, S., Agrawal, A., & Clark, B. (2021). Local Climate Action Planning as a Tool to Harness the Greenhouse Gas Emissions Mitigation and Equity Potential of Autonomous Vehicles and On-Demand Mobility. *Mineta Transportation Institute Publications*. https://doi.org/10.31979/mti.2020.1818

An, L., Yang, X., Zhang, Y., Zhang, Z., Hu, J., & Wang, H. (2019). Modeling System Dynamics of Mixed Traffic with Partially Connected and Automated Vehicles*. *2019 IEEE Intelligent Transportation Systems Conference (ITSC)*, 2569–2569. https://doi.org/10.1109/ITSC.2019.8916935

Arias-Molinares, D., & García-Palomares, J. C. (2020). The Ws of MaaS: Understanding mobility as a service from a literature review. *IATSS Research*, *44*(3), 253–263. https://doi.org/10.1016/j.iatssr.2020.02.001

Azimi, M., Zhou, L., & Qi, Y. (2021). *EXPLORING THE IMPACT OF INFRASTRUCTURE ON BIKE SHARING SYSTEM PERFORMANCE IN HOUSTON CITY* (2020 Project 15). The University of North Carolina at Charlotte- Center for Advanced Multimodal Mobility Solutions and Education. https://cammse.charlotte.edu/sites/cammse.charlotte.edu/files/media/CAMMSE-UNCC-2020-UTC-Project-Report-15-Azimi-Final.pdf

Ban, X. (Jeff), & Li, W. (2018). *Connected Vehicle Based Traffic Signal Optimization*. C2 SMART-Connected Cities with Smart Transportation; University of Washington. https://archive.c2smart.engineering.nyu.edu//wp-content/uploads/2018/07/TrafficSignalOptimizationinConnectedCities-FinalReport.pdf

Barajas, J. M., & Brown, A. (2021). Not minding the gap: Does ride-hailing serve transit deserts? *Journal of Transport Geography*, *90*, 102918. https://doi.org/10.1016/j.jtrangeo.2020.102918

Brown, A. (2021). Not All Fees are Created Equal: Equity Implications of Ride-hail Fee Structures. https://doi.org/10.1016/j.tranpol.2022.05.001

Brown, A. (2019). Prevalence and Mechanisms of Discrimination: Evidence from the Ride-Hail and Taxi Industries. *Journal of Planning Education and Research*, 0739456X19871687. https://doi.org/10.1177/0739456X19871687

Brown, A. (2021). *Scooters are here, but where do they go? Aligning scooter regulations with city goals*. https://trid.trb.org/view/1850462

Brown, A., & Howell, A. (2021). *Mobility for the People: Evaluating Equity Requirements in Shared Mobility Programs | National Institute for Transportation and Communities*. University of Oregon. https://nitc.trec.pdx.edu/research/project/1401

Brown, A., Klein, N. J., Thigpen, C., & Williams, N. (2020). Impeding access: The frequency and characteristics of improper scooter, bike, and car parking. *Transportation Research Interdisciplinary Perspectives*, *4*, 100099. https://doi.org/10.1016/j.trip.2020.100099

Brown, A., & Williams, R. (2021). Equity Implications of Ride-Hail Travel during COVID-19 in California. *Transportation Research Record*, 03611981211037246. https://doi.org/10.1177/03611981211037246

Buehler, R., & Hamre, A. (2014). *Economic benefits of capital bikeshare: A focus on users and businesses* (No. VT-2013-06). Mid-Atlantic Universities Transportation Center. https://rosap.ntl.bts.gov/view/dot/27421

Cavellos, F. (2020). *Using Microtransit Electric Low Speed Vehicles as a Means for Improving Quality of Life in Miami-Dade County* (National Center for Transit Research CUTR-NCTR-RR-2020-25).

University of South Florida. https://digitalcommons.usf.edu/cgi/viewcontent.cgi?article=1254&context=cutr_nctr

Chapple, K. (2013). *TOD, Infill Housing, and Car Share: A Feasibility Study*. University of California, Berkeley & California Department of Transportation. https://trid.trb.org/view/1236304

Cheng, J. (2022, January). *Data-Driven Optimization for E-Scooter System Design | National Institute for Transportation and Communities*. https://nitc.trec.pdx.edu/research/project/1382

Chow, J. (2020). *Urban Micro-transit Cross-sectional Study for Service Portfolio Design*. New York University Tandon School of Engineering Connected Cities for Smart Mobility towards Accessible and Resilient Transportation Center (C2SMART). https://rip.trb.org/view/1697990

Circella, G., & Alemi, F. (2021). *Annual Investigation of Nationwide Mobility Trends: "The Pulse of The Nation" on the 3 Revolutions | National Center for Sustainable Transportation* (65A0686 Task Order 037 and DOT 69A3551747114). University of California, Davis- 3 Revolutions Future Mobility Program. https://ncst.ucdavis.edu/project/annual-investigation-nationwide-mobility-trends-pulse-nation-3-revolutions

Clark, B. (2019). *How Will Autonomous Vehicles Change Local Government Budgeting and Finance? Case Studies of On-Street Parking, Curb Management, and Solid Waste Collection* (NITC-SS-1174; p. 54). University of Oregon. https://nitc.trec.pdx.edu/research/project/1174

Clark, B., & Brown, A. (2020). *How Are Uber/Lyft Shaping Municipal On-Street Parking Revenue?* (SSRN Scholarly Paper ID 3591268). Social Science Research Network. https://doi.org/10.2139/ssrn.3591268

Clark, B., Larco, N., & Mann, R. F. (2017). *The Impacts of Autonomous Vehicles and E-Commerce on Local Government Budgeting and Finance* (SSRN Scholarly Paper ID 3009840). Social Science Research Network. https://doi.org/10.2139/ssrn.3009840

Clark, B. Y., & Brown, A. (2021). What does ride-hailing mean for parking? Associations between on-street parking occupancy and ride-hail trips in Seattle. *Case Studies on Transport Policy*, *9*(2), 775–783. https://doi.org/10.1016/j.cstp.2021.03.014

Currans, K., Ewing, R., & Iroz-Elardo, N. (2021, September). *Scooting to a New Era in Active Transportation: Examining the Use and Safety of E-Scooters | National Institute for Transportation and Communities*. https://nitc.trec.pdx.edu/research/project/1281/

Currans, K., & Howell, A. (2022). *Accessing Opportunities for Household Provisioning Post-COVID-19 | National Institute for Transportation and Communities*. https://nitc.trec.pdx.edu/research/project/1435/

Davis, B. A., & Figliozzi, M. A. (2013). A methodology to evaluate the competitiveness of electric delivery trucks. *Transportation Research Part E: Logistics and Transportation Review*, *49*(1), 8–23. https://doi.org/10.1016/j.tre.2012.07.003

Deitz, S. (2021). *Free Movement: Enhancing Open Data to Facilitate Independent Travel for Persons with Disabilities* (NITC-DD-1374). University of Oregon. https://nitc.trec.pdx.edu/research/project/1374

Dill, J., & McNeil, N. (2021). Are Shared Vehicles Shared by All? A Review of Equity and Vehicle Sharing. *Journal of Planning Literature*, *36*(1), 5–30. https://doi.org/10.1177/0885412220966732

Dill, J., McNeil, N., & Howland, S. (2019). Effects of peer-to-peer carsharing on vehicle owners' travel behavior. *Transportation Research Part C: Emerging Technologies*, *101*, 70–78. https://doi.org/10.1016/j.trc.2019.02.007

Fehr & Peers. (2022). *Dynamic Curbside Management: Keeping Pace with New and Emerging Mobility and Technology in the Public Right-of-Way* [Government]. https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4868

Feng, W., & Figliozzi, M. A. (2012). Conventional vs Electric Commercial Vehicle Fleets: A Case Study of Economic and Technological Factors Affecting the Competitiveness of Electric Commercial Vehicles in the USA. *Procedia - Social and Behavioral Sciences*, *39*, 702–711. https://doi.org/10.1016/j.sbspro.2012.03.141

Fickas, S. (2021). *Green Waves, Machine Learning, and Predictive Analytics: Making Streets Better for People on Bikes* (NITC-RR-1299; pp. 1–23). University of Oregon. https://nitc.trec.pdx.edu/research/project/1299

Figliozzi, M. A. (2011). The impacts of congestion on time-definitive urban freight distribution networks CO2 emission levels: Results from a case study in Portland, Oregon. *Transportation Research Part C: Emerging Technologies*, *19*(5), 766–778. https://doi.org/10.1016/j.trc.2010.11.002

Figliozzi, M. A. (2017). Lifecycle modeling and assessment of unmanned aerial vehicles (Drones) CO2e emissions. *Transportation Research Part D: Transport and Environment*, *57*, 251–261. https://doi.org/10.1016/j.trd.2017.09.011

Figliozzi, M. A. (2020). Carbon emissions reductions in last mile and grocery deliveries utilizing air and ground autonomous vehicles. *Transportation Research Part D: Transport and Environment*, *85*, 102443. https://doi.org/10.1016/j.trd.2020.102443

Figliozzi, M., & Jennings, D. (2020). Autonomous delivery robots and their potential impacts on urban freight energy consumption and emissions. *Transportation Research Procedia*, *46*, 21–28. https://doi.org/10.1016/j.trpro.2020.03.159

Fuchs, S., & Shehadeh, R. (2017). *The department of transportation of the future* [Private Sector]. McKinsey & Company. https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/the-department-of-transportation-of-the-future

Garcia-Colberg, M. (2021). *Customer Education and Awareness of On-Demand Mobility* [In Progress]. Transportation Research Board. https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5175

Gelbal, S. Y., Aksun-Guvenc, B., & Guvenc, L. (2020). SmartShuttle: Model Based Design and Evaluation of Automated On-Demand Shuttles for Solving the First-Mile and Last-Mile Problem in a Smart City. *arXiv preprint* https://arxiv.org/abs/2012.12431

Germany, J., & Sperranza, P. (2014, June). *Streets Portals: Urban User Interface "Test Bed" Prototype for Bikeshare*. https://nitc.trec.pdx.edu/research/project/738

Hampshire, R. C., Jordon, D., & Sasanuma, K. (2014). *Smart Parking*. https://trid.trb.org/View/1508605

Hansen, M., Walker, J., & Lin, P.-S. (2021). *Multimodal strategies for mitigating congestion from urban parcel delivery*. National Institute for Congestion Reduction University of South Florida; University of California, Berkeley. https://trid.trb.org/View/1885435

Harper, C., & Fan, Z. (2021). *Environmental Impacts of Short Car Trip Replacement with Micromobility Modes* (No. 69A3551747111). Carnegie Mellon University- Mobility 21. https://ppms.cit.cmu.edu/media/project_files/Final_Report_-_310.pdf

Hensher, D. A., Mulley, C., Ho, C., Wong, Y., Smith, G., & Nelson, J. D. (2020). *Understanding Mobility as a Service (MaaS): Past, Present and Future*. Elsevier. https://www.sciencedirect.com/book/9780128200445/understanding-mobility-as-a-service-maas

Howell, A., Tan, H., Brown, A., Schlossberg, M., Karlin-Resnick, J., Lewis, R., Anderson, M., Larco, N., Tierney, G., Carlton, I., Kim, J., & Steckler, B. (2020). *Multilevel Impacts of Emerging Technologies on City Form and Development*. https://scholarsbank.uoregon.edu/xmlui/handle/1794/25191

Howland, S., McNeil, N., Broach, J., Rankins, K., MacArthur, J., & Dill, J. (2017). Current Efforts to Make Bikeshare More Equitable: Survey of System Owners and Operators. *Transportation Research Record*, *2662*(1), 160–167. https://doi.org/10.3141/2662-18

Huang, K., Yang, X., Lu, Y., Mi, C. C., & Kondlapudi, P. (2018). Ecological Driving System for Connected/Automated Vehicles Using a Two-Stage Control Hierarchy. *IEEE Transactions on Intelligent Transportation Systems*, *19*(7), 2373–2384. https://doi.org/10.1109/TITS.2018.2813978

Hyun, K., Cronley, C., Naz, F., Robinson, S., & Harwerth, J. (2019). *Assessing Viability of Car-Sharing for Low-Income Communities* (CTEDD 018-04 SG). University of Texas, Arlington- Center for Transportation, Equity, Decisions & Dollars (CTEDD). https://trid.trb.org/view/1641109

Ipek, S. (2023). *Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas | Safe-D: Safety through Disruption* [Texas A&M- Texas Transportation Institute]. https://safed.vtti.vt.edu/projects/delving-into-safety-considerations-of-e-scooters-a-case-study-of-austin-texas/

Iroz-Elardo, N. (2021, July). *E-Scooters and Public Health: Understanding the Implications of E-Scooters on Chronic Disease | National Institute for Transportation and Communities*. https://nitc.trec.pdx.edu/research/project/1358

Iroz-Elardo, N., & Currans, K. (2021). *Injury Burden of Introducing E-Scooters: A Review of E-Scooter Injury Studies Using Retrospective Review of Emergency Department Records, 2015–2019*. https://journals.sagepub.com/doi/abs/10.1177/03611981211032216

Ishak, S., Osman, O., Codjoe, J., Mousa, S., & Bakhit, P. (2016). *Development of a Simulation Test Bed for Connected Vehicles using the LSU Driving Simulator*. National Transportation Center, University of Maryland; Louisiana State University, Baton Rouge Civil & Environmental Engineering Department. https://mti.umd.edu/sites/mti.umd.edu/files/LSU_Maryland_Final%20Report_0.pdf

Jaller, M. (2022). *Coping with the Rise of E-Commerce Generated Home Deliveries Through Innovative Last-Mile Technologies and Strategies*. National Center for Sustainable Transportation University of California, Davis. https://trid.trb.org/View/1881973

Jaller, M., & Niemeier, D. (2022). *Dock-based and Dockless Bikesharing Systems: Analysis of Equitable Access for Disadvantaged Communities | National Center for Sustainable Transportation*. University of California Davis- National Center for Transportation. https://ncst.ucdavis.edu/project/dock-based-and-dockless-bikesharing-systems-analysis-equitable-access-disadvantaged

Jaller, M., Rodier, C., Zhang, M., Lin, H., & Lewis, K. (2021). *Fighting for Curb Space: Parking, Ride-Hailing, Urban Freight Deliveries, and Other Users* (p. 126). University of California Davis. https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/final-reports/ca21-3397-final-report-a11y.pdf

Jaller, M., & Xiaodong, Q. (2022). *Optimizing Bikeshare Service to Connect Affordable Housing Units with Transit Services | National Center for Sustainable Transportation* [University of California, Davis- National Center for Transportation]. https://ncst.ucdavis.edu/project/optimizing-bikeshare-service-connect-affordable-housing-units-transit-services

Jiao, J., Bischak, C., Chen, Y., Guerra, E., & Pan, Q. (2019). *The Role of Transportation Networking Companies in Megaregion Mobility* (No. CM2-#38). Article CM2- #38. https://trid.trb.org/View/1679239

Jordan, B., Makler, J., & Bertini, R. (2014). State of Knowledge and Practice: Opportunities for Intelligent Transportation Systems in the Energy Arena. *Transportation Research Record*, *2423*(1), 1–9. https://doi.org/10.3141/2423-01

Karimpour, A., Anderson, J. C., Kothuri, S., & Wu, Y.-J. (2021). Estimating pedestrian delay at signalized intersections using high-resolution event-based data: A finite mixture modeling method. *Journal of Intelligent Transportation Systems*, 1–18. https://doi.org/10.1080/15472450.2021.1926246

Karimpour, A., Kluger, R., & Wu, Y.-J. (2020). Traffic sensor data-based assessment of speed feedback signs. *Journal of Transportation Safety & Security*, 1–24. https://doi.org/10.1080/19439962.2020.1731038

Klauer, C. (2022). *An Evaluation of Road User Interactions with E-Scooters*. Virginia Tech University-Transportation Institute. https://safed.vtti.vt.edu/projects/an-evaluation-of-road-user-interactions-with-e-scooters/

Klein, N. J., Ralph, K., Thigpen, C., & Brown, A. (2021). Political Partisanship and Transportation Reform. *Journal of the American Planning Association*. https://doi.org/10.1080/01944363.2021.1965495

Kortum, K. & National Academies of Sciences, Engineering, and Medicine. (2021). *The Role of Transit, Shared Modes, and Public Policy in the New Mobility Landscape*. The National Academies Press. https://doi.org/10.17226/26053

Lakshmanan, S. (2021). *Reliable V2V Communication Networks: Applications in Fuel-Efficient Platooning* [Technical Report]. University of Michigan, Ann Arbor, Transportation Research Institute. https://doi.org/10.7302/381

Larco, N., Howell, A., Lewis, R., & Steckler, B. (2018). *AVs in the Pacific Northwest: Reducing Greenhouse Gas Emissions in a Time of Automation*. https://scholarsbank.uoregon.edu/xmlui/handle/1794/25198

Lee, Y.-J. (2022). *Integrated Optimal Transit Network Design with MaaS Implementation*. Morgan State University. http://www2.morgan.edu/school_of_engineering/research_centers/national_transportation_center/research/new_projects/maas_implementation.html

Lee, Y.-J., Shin, H.-S., & Schonfeld, P. (2022). *User Preference Analysis for Mobility-as-a-Service (MaaS) and Its Impact in Maryland* (No. 69A43551747123). Morgan State University. https://rip.trb.org/view/1872003

Lewis, R., & Clark, B. Y. (2021). Retooling local transportation financing in a new mobility future. *Transportation Research Interdisciplinary Perspectives*, *10*, 100388. https://doi.org/10.1016/j.trip.2021.100388

Liu, C. (2022). *Strategic Deployment of Drone Centers and Fleet Size Planning for Drone Delivery in Utah*. Dept. of Civil and Environmental Engineering University of Utah; Mountain-Plains Consortium North Dakota State University. https://trid.trb.org/View/1749191

Liu, X. C. (2020). *MPC - The Impact of the Mobility as a Service Mode on Transit Access* (MPC-608). University of Utah. https://www.mountain-plains.org/research/details.php?id=505

MacArthur, J., & Dill, J. (2021, August). *Evaluation of Portland Shared E-Scooter Pilot Program Goals and Outcomes | National Institute for Transportation and Communities*. https://nitc.trec.pdx.edu/research/project/1284

MacArthur, J., Harpool, M., & Scheppke, D. (2019). *How Technology Can Affect the Demand for Bicycle Transportation: The State Of Technology and Projected Applications of Connected Bicycles* (NITC-RR-759; p. 31). Portland State University. https://nitc.trec.pdx.edu/research/project/759

MacArthur, J., McNeil, N., & Broach, J. (2020, December 3). *National Scan of Bike Share Equity Programs | National Institute for Transportation and Communities*. https://nitc.trec.pdx.edu/research/project/1278

MacArthur, J., McNeil, N., Cummings, A., & Broach, J. (2020). Adaptive Bike Share: Expanding Bike Share to People with Disabilities and Older Adults. *Transportation Research Record*, *2674*(8), 556–565. https://doi.org/10.1177/0361198120925079

Machemehl, R. (2023). *Impacts of Speed on Dockless Electric Scooter Crashes (Phase II)*. University of North Carolina Charlotte, Center for Advanced Multimodal Mobility Solutions and Education. https://trid.trb.org/View/1881795?ajax=1

Martin, M. (2021). *Computer and Internet Use in the United States, 2018* (ACS-49). US Census Bureau. https://www.census.gov/library/publications/2021/acs/acs-49.html

Mason, D. (2021, January). *The Impact of Ride Hail Services on the Accessibility of Nonprofit Services | National Institute for Transportation and Communities*. https://nitc.trec.pdx.edu/research/project/1357

McFadden, M., Ullman, H., & McRae, G. (2019). *I See Myself in that Career: Exploring Methods to Attract the Next Generation Transportation Workforce* (p. 115) [Academic Research REport]. University of California Davis, National Center for Sustainable Transportation. https://escholarship.org/uc/item/82r0k1ch

McNeil, N., Dill, J., MacArthur, J., & Broach, J. (2017). Breaking Barriers to Bike Share: Insights from Bike Share Users. *TREC Final Reports*. https://doi.org/10.15760/trec.191

McNeil, N., Dill, J., MacArthur, J., Broach, J., & Howland, S. (2017). Breaking Barriers to Bike Share: Insights from Residents of Traditionally Underserved Neighborhoods. *TREC Final Reports*. https://doi.org/10.15760/trec.176

McNeil, N., Macarthur, J., & Broach, J. (2020). Making Equity a Sustainable Part of Bike Share. *Institute of Transportation Engineers. ITE Journal*, *90*(5), 16–18. https://www.ite.org/ITEORG/assets/File/ITEJ%20Published/2020/ITE_ITE_May2020.pdf#page=16

McQueen, M., Abou-Zeid, G., MacArthur, J., & Clifton, K. (2021). Transportation Transformation: Is Micromobility Making a Macro Impact on Sustainability? *Journal of Planning Literature*, *36*(1), 46–61. https://doi.org/10.1177/0885412220972696

Mollenhauer, M. (2021). *E-Scooter Safety Assessment and Campus Deployment Planning* [TRID]. Virginia Tech - Safety through Disruption University Transportation Center (Safe-D). https://safed.vtti.vt.edu/projects/e-scooter-safety-assessment-and-campus-deployment-planning/

Mondschein, A. S. (2015). Virginia Sustainable Travel Choices: Effects of Land Use and Location on Current and Future Travel Options. https://rosap.ntl.bts.gov/view/dot/34731

Niemeier, D., & Xiaodong, Q. (2018). *High Impact Prioritization of Bikeshare Program Investment to Improve Underserved Communities' Access to Jobs and Essential Services* (National Center for Sustainable Transportation Research Report). University of California Davis. https://ncst.ucdavis.edu/research-product/high-impact-prioritization-bikeshare-program-investment-improve-underserved

Pande, A., & Barbeau, S. (2021). *Where to? Origins and Destinations of TNC and Transit Trips Based on Mobile Devices*. California State Polytechnic University, San Luis Obispo California Polytechnic State University; University of South Florida, Tampa Center for Urban Transportation Research; Center for Transportation Equity, Decisions, & Dollars University of Texas at Arlington. https://trid.trb.org/View/1728213

Pani, A., Mishra, S., Golias, M., & Figliozzi, M. (2020). Evaluating public acceptance of autonomous delivery robots during COVID-19 pandemic. *Transportation Research Part D: Transport and Environment*, *89*, 102600. https://doi.org/10.1016/j.trd.2020.102600

Paleti, R., Cetin, M., Sohrabi, S., Balan, L., Rakha, H., & Elhenawy, M. (2018). Real-Time System State Prediction & Optimal Rebalancing Strategies for Public Bike Sharing Systems. https://trid.trb.org/view/1571748

Peha, J. M., Ligo, A. K., & Pesner, J. (2020). Cost-Effective Designs of Smart City Technologies for Vehicular Communications. https://ppms.cit.cmu.edu/media/project_files/final_report_274_Cost-Effective_Designs_of_Smart_City_Technologies_for_Vehicular_Communications.pdf

Peng, Z.-R. (2021). *Examining Data Needs and Implementation Process of AV-based Microtransit Service: A Case Study in Lake Nona – International Center For Adaptation Planning and Design*. Department of Urban and Regional Planning College of Design, Construction and Planning University of Florida. https://dcp.ufl.edu/iadapt/examining-data-needs-and-implementation-process-of-av-based-microtransit-service-a-case-study-in-lake-nona/

Pew Research Center, Washington, S. 800, & Inquiries, D. 20036 U.-419-4300 | M.-857-8562 | F.-419-4372 | M. (2021). Demographics of Mobile Device Ownership and Adoption in the United States. *Pew Research Center: Internet, Science & Tech*. https://www.pewresearch.org/internet/fact-sheet/mobile/

Pimentel, D., Koglin, T., & Lowry, M. (2020). *Taming and Tapping the Bikeshare Explosion- Review of Shared Micro-mobility Law*. Pacific Northwest Transportation Consortium (PacTrans) USDOT University Transportation Center for Federal Region 10- University of Washington. https://digital.lib.washington.edu/researchworks/bitstream/handle/1773/46274/Lowry%20Taming_Tapping_Bikeshare%20Explosion.pdf?sequence=1&isAllowed=y

Pradhan, A., Jeong, H., & Bao, S. (2020). *Connected and Automated Vehicle Based Intersection Maneuver Assist Systems (CAVIMAS) and Their Impact on Driver Behavior, Acceptance, and Safety*. Center for Connected and Automated Transportation; University of Michigan Dearborn; University of Illinois Chicago; University of Massachusetts Amherst. https://deepblue.lib.umich.edu/bitstream/handle/2027.42/156048/Connected_and_Automated_Vehicle_Based_Intersection_Maneuver_Assist_Systems_CAVIMAS.pdf?sequence=4

Qian, S., Ma, W., Choudhry, A., Cho, S., Jia, J., McHugh, J., ... & Yuan, M. (2021). Smart Right-of-Way Permitting System for the City of Pittsburgh: Coordination, Pricing and Enforcement. https://rosap.ntl.bts.gov/view/dot/60112

Rakha, H., Chen, H., Almannaa, M. H., Kamalanathsharma, R., El-Shawarby, I., & Loulizi, A. (2016). *Field Testing of Eco-Speed Control Using V2I Communication*. Virginia Tech Transportation Institute (VTTI), University of Virginia (UVA) Center for Transportation Studies, and Morgan State University (MSU. https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3824

Ravishanker, N., & Konduri, K. (2019). *Are Transportation Network Companies Synergistic with Other Shared Ride Mode Offerings? An Exploratory Analysis of Demand Data from NYC Utilizing High Resolution Spatiotemporal Models* (2019 Project 10). The University of North Carolina at Charlotte- Center for Advanced Multimodal Mobility Solutions and Education. https://cammse.charlotte.edu/sites/cammse.charlotte.edu/files/media/CAMMSE-UNCC-2019-UTC-Project-Report-10-Ravishanker-Konduri-Final.pdf

Reeb, T. (Ed.). (2019). *Empowering the New Mobility Workforce: Educating, Training, and Inspiring Future Transportation Professionals*. Elsevier. https://www.elsevier.com/books/empowering-the-new-mobility-workforce/reeb/978-0-12-816088-6

Sanguinetti, A., Chakraborty, D., Amenta, N., & Alston-Stepnitz, E. (2022). *Developing a Vehicle Cost Calculator to Promote Electric Vehicle Adoption among TNC Drivers*. National Center for Sustainable Transportation University of California Davis. https://trid.trb.org/View/1875155

Schlossberg, M., & Brinton, H. (2019, December). *Matching the Speed of Technology with the Speed of Local Government: Developing Codes and Policies Related to the Possible Impacts of New Mobility on Cities | National Institute for Transportation and Communities*. https://nitc.trec.pdx.edu/research/project/1216/

Shaheen, S., Cohen, A., Dowd, M., & Richard, D. (2019). *A Framework for Integrating Transportation into Smart Cities*. Mineta Transportation Institute, San Jose State University. https://transweb.sjsu.edu/sites/default/files/1705-Shaheen-Framework-Transportation-Smart-Cities.pdf

Shaheen, S., Frick, K., & Ipek, S. (2022). *Congestion Using New Mobility Platforms: Understanding Curb Management and Targeted Incentive Policies to Increase Pooling*. University of California, Berkeley & Texas A&M. https://trid.trb.org/View/1737963

Shaheen, S., & Ipek, S. (2022). *Advancing Social/Racial Equity and Congestion Relief: Understanding the Travel Needs of Marginalized Populations that Rely on Transportation Network Companies*. University of California, Berkeley & Texas A&M. https://trid.trb.org/View/1885422

Skov, J., Toneys, A., & Brown, A. (2020). *The Carbon Footprint of Ride-Hailing: GHG Inventory Methodology* (p. 32) [Academic]. University of Oregon and Good Company. https://www.digitalenergyenvironment.org/research-teams/ggefets/

Steckler, B., Howell, A., Coia, J., Kalpowitz, G., & New Mobility Alliance. (2020). *Perfecting Policy with Pilots: New Mobility and AV Urban Delivery Pilot Project Assessment*. Urbanism Next, The University of Oregon. https://www.urbanismnext.org/resources/perfecting-policy-with-pilots-new-mobility-and-av-urban-delivery-pilot-project-assessment

Steckler, B., & Lewis, R. (2019). *Emerging Technologies and Cities: Assessing the Impacts of New Mobility on Cities | National Institute for Transportation and Communities*. University of Oregon. https://nitc.trec.pdx.edu/research/project/1249

Stoll, N. B., Glick, T., & Figliozzi, M. A. (2016). Using High-Resolution Bus GPS Data to Visualize and Identify Congestion Hot Spots in Urban Arterials. *Transportation Research Record*, *2539*(1), 20–29. https://doi.org/10.3141/2539-03

Tan, H., McNeil, N., MacArthur, J., & Rodgers, K. (2021). Evaluation of a Transportation Incentive Program for Affordable Housing Residents. *Transportation Research Record: Journal of the Transportation Research Board*, *2675*(8), 240–253. https://doi.org/10.1177/0361198121997431

Thales Group. (2021). *What is a smart city? Technology and examples*. https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/inspired/smart-cities

TNO. (2020). *Policy Options to Steer Mobility as a Service: International Case Studies* (p. 57). https://www.tno.nl/en/about-tno/news/2021/1/governance-models-mobility-as-a-service-maas/

Tufte, K., Head, L., MacArthur, J., & Keaton, S. (2021). *Connected Streetcar Project* [In Progress]. Portland State University. https://nitc.trec.pdx.edu/research/project/1182

Ursaki, J., & Aultman-Hall, L. (2015). *Quantifying the Equity of Bikeshare Access in US Cities* [TRC Report 15-011]. The University of Vermont- Transportation Research Center. https://rosap.ntl.bts.gov/view/dot/36739

Wang, L., Broach, J., & Yang, H. (2018). Modeling for New Modes: Autonomous Vehicles & Shared Rides. *TREC Project Briefs*. https://nitc.trec.pdx.edu/research/project/881

Wang, L., & Wu, Y.-J. (2020). *Land Use and Transportation Policies for a Sustainable Future with Autonomous Vehicles: Scenario Analysis with Simulations*. Portland State University, University of Arizona. https://nitc.trec.pdx.edu/research/project/1242

Xilei, Z. (2020). *Micro-Mobility as a Solution to Reduce Urban Traffic Congestion*. University of Florida-Southeastern Transportation Research, Innovation, Development and Education Center (STRIDE). https://trid.trb.org/view/1938188

Xing, Y., & Pike, S. (2021). *Exploring the Consumer Market and Environmental Impacts of Microtransit Services in Sacramento and Citrus Heights, California | National Center for Sustainable Transportation* [In Progress]. University of California, Davis & California Department of Transportation. https://ncst.ucdavis.edu/project/exploring-consumer-market-and-environmental-impacts-microtransit-services

Yang, X. T., Zhang, Z., & Zhang, Z. (2018). *Vehicle Sensor Data (VSD)-Based Traffic Control in Connected Automated Vehicle (CAV) Environment* (NITC-SS-1175; p. 41). University of Utah. https://nitc.trec.pdx.edu/research/project/1175

Yang, X. (Terry), Chang, G.-L., Zhang, Z., & Li, P. (Taylor). (2019). Smart Signal Control System for Accident Prevention and Arterial Speed Harmonization under Connected Vehicle Environment. *Transportation Research Record*, *2673*(5), 61–71. https://doi.org/10.1177/0361198119837242

Zhang, P., Chen, X., Xu, S., Fu, H., Joe-Wong, C., Zhang, L., & Noh, H. Y. (2019). Actuation System For City-Wide Sensing and Ride Distribution Using Managed Vehicular Fleets. https://rosap.ntl.bts.gov/view/dot/53885

Zhang, Y., & Guo, Y. (2020). *Understand usage patterns of e-scooter sharing and policy implications* (No. 69A3551747119). School of Civil and Environmental Engineering University of South Florida. https://rosap.ntl.bts.gov/view/dot/56091

Appendix A. New Mobility and Technologies Definitions

Category	Technolo gy	Definition	Examples	Source
NEW MOBILITY VEHICLES, DEVICES AND SERVICES				
Micromobility	Bikeshare	Bikesharing users access bicycles on an as-needed basis for one-way (point-to-point) or roundtrip travel using one of three bikesharing models: (1) station-based bikesharing, (2) dockless, and (3) hybrid bike sharing systems. These systems currently operate with both traditional (motorless) bicycles and electric bicycles or "e-bikes." There are also closed campus and P2P bike sharing systems. Closed-campus bike sharing systems are deployed at university and office campuses, and they are only available to the particular campus community they serve (e.g., students).	Capital Bikeshare, Citi Bike, Bay Wheels	Shaheen et al., 2020 Shaheen & Christensen, 2014
	E-scooters	Lightweight, motorized transportation devices, with handlebars, that obtain a maximum speed of 20 miles per hour when powered by motor (Regulation of Electric Scooters, 2019). Can be used in a shared fleet or individually owned.	Bird, Lyft, Lime	Pettersen et al., 2019
	Scooters	Also called mopeds, scooters have two or three wheels as four-wheeled vehicles are generally considered cars or off-road vehicles. An electric motor and automatic transmission. A moped may also include pedals, if it's not entirely propelled by its motor. A moped must only be able to maintain a maximum speed of under 30 miles per hour on level ground.	Revel	Oregon Department of Transportation, 2019
Carsharing	Individually owned-cars	Also known as peer-to-peer (P2P) carsharing employs privately owned vehicles made temporarily available for shared use by an individual or members of a P2P carsharing network. Expenditures, such as insurance, are generally covered by the P2P operator during the access period. In exchange for providing the service, operators keep a portion of the usage fee. Members can access vehicles through a direct key or combination transfer from the owner or through operator-installed technology that enables "unattended access."	Turo	Shaheen et al., 2018

	Fleets	Station-based car sharing includes a system where cars are picked up and returned at a fixed location. In free-floating car sharing, the car fleet is entered and left parking in a public space. Smart phones and web technology have allowed a subscriber to the car sharing service to use a car within a service area and not return it to its original location, allowing for a flexible use of the car.	Gig Car Share	Heinrichs et al., 2017
Transportation Network Companies		On-demand ride services where rides are arranged through a mobile app to connect the passenger with a driver, often a private individual driving their personal vehicle. Also referred to as ride-sourcing, ride-hailing, and e-hail.	Uber, Lyft	Erhardt et al., 2019
Microtransit		An on-demand transit service can incorporate flexible routing, flexible scheduling or both.	Via	
Autonomous Vehicles	Passenger Vehicles	SAE defines a vehicle as autonomous when it includes features that can either drive the vehicle under limited conditions and will not operate unless all required conditions are met or when the vehicle can drive under all conditions. CAV's can be used for routing with microscale traffic information, coordinated platooning using traffic signals information and energy efficient driving with guaranteed parking.	Waymo	SAE International, 2018 & Guanetti et al., 2018
	Goods Delivery	Also called autonomous delivery vehicles (ADVs), electric and self-driving ground vehicles driving on sidewalks and streets delivering goods purchased through e-commerce to the consumer. Usually used in last-mile delivery. This technology is still in the early stages.	NUMO	Carotenuto et al., 2018;
Drones	UAVs	Unmanned Aerial Vehicles (UAVs) or drones can be used to deliver packages and other items via aerial flight directly to the consumer.	Amazon, UPS	Goodchild & Toy, 2018
	PDDs	Personal delivery devices (PDD) are a ground-based delivery device that is manufactured for transporting cargo or goods and is operated by a driving system that allows for autonomous and/or remote operations.	Starship, Kiwibot,	Pennsylvania Department of Transportation, 2020
TECHNOLOGY				
E-commerce and urban goods delivery		Specifically within the business to consumer (B2C) market, this includes the delivery of a parcel to a consumer's address. Growing demand for these deliveries increase traffic and congestion problems and environmental pollution. o Alternatives include point to point delivery and the use of lockers.	Amazon, Uber Eats, GrubHub	Kapser & Abdelrahman, 2020
Mobility as a Service (MaaS)		The integration of transport services to provide one-stop access through a common interface.		Hensher et al., 2020

Pricing	Congestion /Demand Management	The use of increased fees to remove a small fraction of vehicles from a congested roadway, allowing the system to flow more freely through the same physical space. Common types include 1) variably priced lanes 2) variable tolls on entire roadways 3) cordon charges 4) area-wide charges.		Federal Highway Administration, 2019
Smart City Technology		A smart city is a framework, predominantly composed of Information and Communication Technologies (ICT), to develop, deploy, and promote sustainable development practices to address growing urbanization challenges	Cisco Kinetic, Schneider Electric, Siemens	Thales Group, 2021
	V(ehicle)2V	Communication used to coordinate multi-vehicle maneuvers, establish a formation, exchange vehicle state, and create short headway time between vehicles.		Guanetti et al., 2018
	V2i(infrastructure)	Communication between vehicles and infrastructure that can provide information about traffic and signalized intersections in the downstream road which can result in substantial energy savings.		Guanetti et al., 2018
	T2I	A system designed to enhance the experience, comfort, efficiency, and safety of people on bikes by making traffic signal processes and information more attentive to cyclists. The goal of the system is to increase the likelihood that someone on a bike will experience a green light when approaching a signal. There are two primary aspects of this effort: 1) active traffic signal engagement by approaching bicycle users; and 2) passive information sharing to cyclists of traffic signal status		Fickas, 2019
	T2V	This technology falls within the category of V2X and aims to help improve the visibility and coordination of vehicles and pedestrians while in the same street zone		Fickas, 2019

Appendix B: Table of NITC Research

This table includes a summary of research funded by NITC related to new mobility vehicles and technology topics. The table is organized alphabetically by research topic, subtopic, and then by year completed (from newest to oldest).

Topic	Subtopic	Title	Authors	Institution	Category	Status
Autonomous Vehicles	Policy and Regulations	Land Use and Transportation Policies for a Sustainable Future with Autonomous Vehicles: Scenario Analysis with Simulations	Liming Wang, Yao-Jan Wu	Portland State University, University of Arizona	New Mobility	In Progress: 2020
	Policy and Regulations	Matching the Speed of Technology with the Speed of Local Government: Developing Codes and Policies Related to the Possible Impacts of New Mobility on Cities	Marc Schlossberg, Heather Brinton	University of Oregon	New Mobility	In Progress: 2019
	Policy and Regulations	Emerging Technologies and Cities: Assessing the Impacts of New Mobility on Cities	Becky Steckler, Rebecca Lewis	University of Oregon	New Mobility	Completed: 2019
	Policy and Regulations	How Will Autonomous Vehicles Change Local Government Budgeting and Finance? A Case Study of Solid Waste, Drop-off/Pick-up Zones, and Parking	Benjamin Clark	University of Oregon	New Mobility	Completed: 2019
Bikeshare	Equity	New Mobility for All: Can Targeted Information and Incentives Help Underserved Communities Realize the Potential Of Emerging Mobility Options?	Nathan McNeil, John MacArthur	Portland State University	New Mobility	In Progress: 2022
	Equity	National Scan of Bike Share Equity Programs	John MacArthur, Nathan McNeil, Joe Broach	Portland State University	New Mobility	In Progress: 2020
	Equity	Evaluating Efforts to Improve the Equity of Bike Share Systems	Nathan McNeil, John MacArthur, Jennifer Dill, Joe Broach,	Portland State University	New Mobility	Completed: 2017

Bikeshare	Equity	Street Portals: Urban User Interface 'Test Bed' Prototype for Bike Shares	Jason Germany, Phillip Speranza	University of Oregon	New Mobility	Completed: 2014
	Economic	Implementing Oregon's Energy Plan: Opportunities for Operations and ITS	John Makler	Portland State University	Technology	Completed: 2012
E-scooters	System Management	Data-Driven Optimization for E-Scooter System Design	Jianqiang Cheng	University of Arizona	New Mobility	In Progress: 2022
	Health and Safety	E-Scooters and Public Health: Understanding the Implications of E-Scooters on Chronic Disease	Nicole Iroz-Elardo	University of Arizona	New Mobility	In Progress: 2021
	Policy and Regulations	Evaluation of Portland Shared E-Scooter Pilot Program Goals and Outcomes	John MacArthur, Jennifer Dill	Portland State University	New Mobility	In Progress: 2021
	Equity	Mobility for the People: Evaluating Equity Requirements in Shared Mobility Programs	Anne Brown, Amanda Howell	University of Oregon	New Mobility	In Progress: 2021
	Health and Safety	Scooting to a New Era in Active Transportation: Examining the Use and Safety of E-Scooters	Kristina Currans, Reid Ewing, Nicole Iroz-Elardo	University of Arizona, University of Utah	New Mobility	In Progress: 2021
	Equity	Transportation Wallet for Residents of Affordable Housing: Evaluation of an Incentives Pilot Program in Portland, OR	Huijun Tan, Nathan McNeil, John MacArthur, Kelly Rodgers,	Portland State University	New Mobility	Completed: 2021
Transportation Network Companies	Equity	The Impact of Ride Hail Services on the Accessibility of Nonprofit Services	Dyanna Mason	University of Oregon	New Mobility	Completed: 2021
Smart Cities	System Management	Data-Driven Mobility Strategies for Multimodal Transportation	Yao-Jan Wu, Xiafeng (Terry) Yang, Sirisha Kothuri	University of Arizona, Portland State University	New Mobility	Completed: 2021
	Equity	Free Movement: Enhancing Open Data to Facilitate Independent Travel for Persons with Disabilities	Shiloh Deitz, Amy Lobben, Henry Luan, Colin Koopman, Stephen Fickas	University of Oregon	Technology	Completed: 2021

	System Management	Incorporate Emerging Travel Modes in the Regional Strategic Planning Model (RSPM) Tool	Liming Wang	Portland State University	New Mobility/ Technology	Completed: 2018
	System Management	Using High-Resolution Bus Detection Data to Improve Travel Time Prediction and Identify Urban Congestion Spots	Miguel Andres Figliozzi	Portland State University	Technology	Completed: 2016
	Economic	Implementing Oregon's Energy Plan: Opportunities for Operations and ITS	John Makler	Portland State University	Technology	Completed: 2012
V2I	System Management	Shortening the Age of Information: Connecting Vehicles to Infrastructure in Real Time	Xianfeng (Terry) Yang, Mingyue Ji	University of Utah	Technology	Completed: 2020
	System Management	Vehicle Sensor Data (VSD) Based Traffic Control in Connected Automated Vehicle (CAV) Environment	Xiafeng (Terry) Yang	University of Utah	Technology	Completed: 2018
V2T	System Management	Green Waves, Machine Learning, and Predictive Analytics: Making Streets Better for People on Bikes	Stephen Fickas, Marc Schlossberg	University of Oregon	Technology	Completed: 2021
	System Management	V2X: Bringing Bikes into the Mix	Stephen Fickas	University of Oregon	Technology	Completed: 2018
V2V	Operational/Pilot s	Connected Streetcar Project	Kristin Tufte, Larry Head, John MacArthur	Portland State University, University of Arizona	Technology	In Progress: 2021
	System Management	Connected Vehicle System Design for Signalized Arterials	Xiafeng (Terry) Yang, Mingyue Ji	University of Utah	Technology	Completed: 2019
	System Management	How Technology Can Affect the Demand for Bicycle Transportation: The State of Technology and Projected Applications of Connected Bicycles	John MacArthur	Portland State University	Technology	Completed: 2018

Appendix C: Table of Technology and New Mobility NITC Researchers

This table includes researchers who have previously received NITC funding, designated by "NITC-NF" in Section 2. The table is organized alphabetically by institution and the researcher's last name.

Researchers	Institution
Joe Broach	Portland State University
Jennifer Dill	Portland State University
Miguel Andres Figliozzi	Portland State University
Sirisha Kothuri	Portland State University
John MacArthur	Portland State University
John Makler	(Former TREC staff)
Nathan McNeil	Portland State University
Kristin Tufte	Portland State University
Liming Wang	Portland State University
Kristina Currans	University of Arizona
Nicole Iroz-Elardo	University of Arizona
Yoa-Jan Wu	University of Arizona
Heather Brinton	University of Oregon
Anne Brown	University of Oregon
Benjamin Clark	University of Oregon
Stephen Fickas	University of Oregon
Jason Germany	(Former University of Oregon faculty)
Amanda Howell	University of Oregon
Rebecca Lewis	University of Oregon
Dyanna Mason	University of Oregon
Phillip Speranza	University of Oregon
Marc Schlossberg	University of Oregon
Becky Steckler	University of Oregon
Reid Ewing	University of Utah
Xiafeng Yang	University of Utah
Mingyue Ji	University of Utah