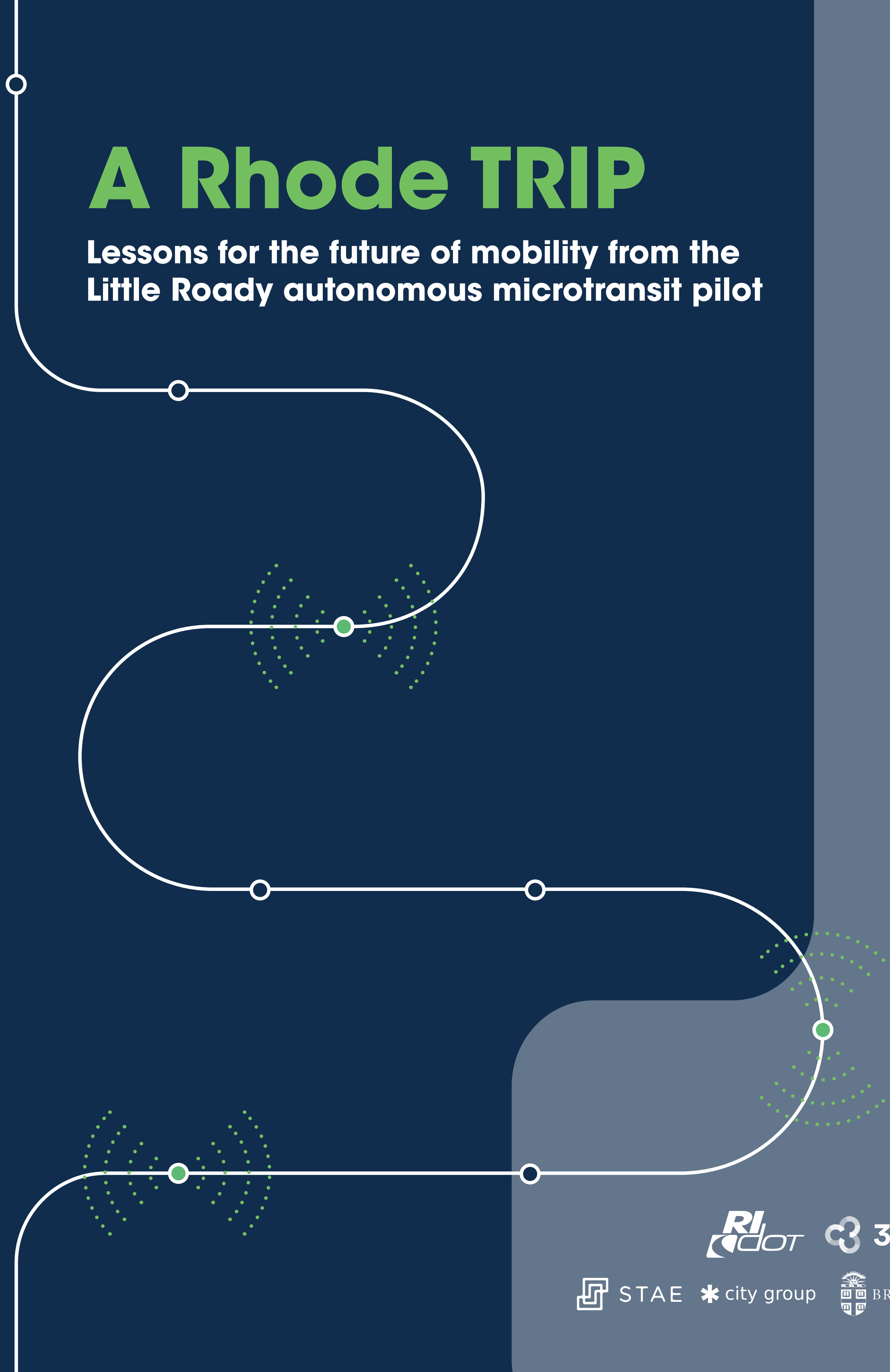
A Rhode TRIP

Lessons for the future of mobility from the Little Roady autonomous microtransit pilot



RIDOT 3×3

STAE city group BROWN

Notice

Quality Assurance Statement

Author's Disclaimer

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Metric Conversion Table

Approximate conversions to SI* units

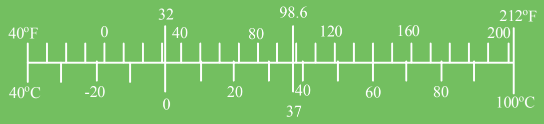
Symbol	When you know	Multiply by	To find	Symbol
Length				
in	inches	25.4	milimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	Miles (status)	1.61	kilometers	km
Area				
in^2	square inches	645.2	milimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	squared miles	2.59	kilometers squared	km^2
ac	acres	0.4046	hectares	ha
Mass (weight)				
oz	Ounces (aydp)	28.35	grams	g
lb	Pounds (aydp)	0.454	kilograms	kg
T	Short tons (2000 lb)	0.907	megagrams	mg
Volume				
fl oz	fluid ounces	29.57	mililiters	mmL
gal	Gallons (liq)	3.785	liters	liters
ft^3	cubic feet	0.0283	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
Temperature (exact)				
°F	Farenheit temperature	5/9 (°F-32)	Celsius temperature	°C
Illumination				
fc	Foot-candles	10.76	lux	lx
fl	foot-lamberts	3.426	candela/m^2	cd/cm^2
Force and Pressure or Stress				
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

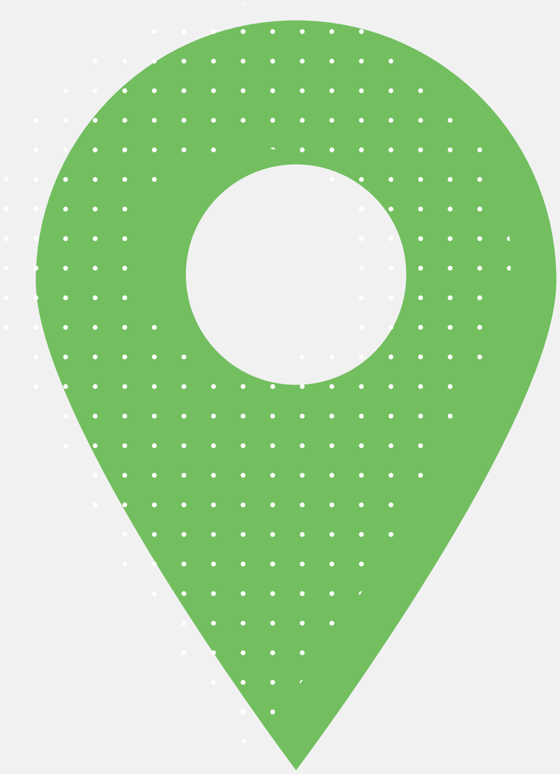
These factors conform to the requirement of FHWA Order 5190.1A

**SI is the symbol for the International System of Measurements*

Approximate conversions to SI* units

Symbol	When you know	Multiply by	To find	Symbol
Length				
mm	milimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	9.621	Miles (status)	mi
Area				
mm^2	milimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
km^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.471	acres	ac
Mass (weight)				
g	grams	0.0353	Ounces (aydp)	g
kg	kilograms	2.205	Pounds (aydp)	kg
mg	megagrams (1000 kg)	1.103	Short tons	mg
Volume				
mmL	mililiters	0.034	fluid ounces	fl oz
liters	liters	0.264	Gallons (liq)	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
Temperature (exact)				
°C	Celsius temperature	9/5 (°C+32)	Fahrenheit temperature	°F
Illumination				
lx	lux	0.0929	Foot-candles	lx
cd/cm^2	candela/m^2	0.2919	foot-lamberts	cd/cm^2
Force and Pressure or Stress				
N	newtons	0.225	pound-force	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi





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16. Abstract
The Little Roady Autonomous Vehicle (AV) shuttle pilot was coordinated by the Rhode Island Department of Transportation and consisted of a free daily shuttle service operated from May 2019 through June 2020 along a twelve-stop, 5.3-mile loop along the Woonasquatucket Corridor in Rhode Island. Key goals of the Little Roady project were to safely introduce and test AV technology in Rhode Island, provide meaningful first/last mile transportation linkages, create economic opportunities, accelerate innovation, and support and evaluate public user experiences. Methods to study the Little Roady project include national and regional surveys, field observations, interviews, and representational state transfer application programming interface (RESTful API) shuttle service operational data. Main findings from the study reflect a steady improvement of pilot operations-related metrics including headways and use of AV mode, infrequent incidents, and generally positive perceptions and experiences reported by riders and operators. However, significant challenges emerged in relation to the public-private partnership at the heart of the project, as data sharing limitations reduced opportunities to analyze key metrics related to technology, performance, and cost. The report concludes with opportunities for future partnerships.

17. Key Words
Autonomous vehicles, microtransit, public-private partnership, department of transportation, first/last mile transit, shuttle pilot, mobility

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Foreword

This is a time of disruption and fast-paced change within the transportation sector. Innovation and new technologies, such as connected and highly automated or autonomous vehicles (CAVs), offer us the potential to grow partnerships, improve mobility, build our economy, reduce negative environmental impacts, and benefit the health and well-being of Rhode Islanders. While the new technologies could bring dramatic changes to the transportation system as we know it, integration of these technologies should be carefully planned and well executed to avoid unintended consequences and to yield the most benefits.

We are at the same point in history as at the beginning of the 20th century. The transportation of people and goods as we know it today is in for a dramatic change. We know that the future is already here, and that not only new technologies are emerging at an accelerated pace, but that expectations and travel behavior of our customers and stakeholders is rapidly changing.

RIDOT sees transportation and mobility as critical aspects of an integrated and comprehensive system of communities, infrastructure, land-use planning, technology, and the natural environment. As one of a handful of states with a 10-year transportation action plan, integrating the planning process for our infrastructure projects with new technologies is critically important to us. To that extent, we are looking to explore the questions, challenges, and opportunities that arise when we merge older infrastructure with the cutting-edge, rapidly accelerating technology that comes with the cars of today and tomorrow.

Our exploration began in April 2017 when we hosted a group of international experts from the World Road Association (PIARC) for a working meeting, where we took the opportunity to have a mini summit on connected and autonomous vehicles. The intent of the summit was to understand what other countries were doing to prepare for the arrival of autonomous vehicles. What we learned from the summit is the need to seize the opportunity and be proactive in this arena.

In less than a year's time, we took steps to form the Rhode Island Transportation Innovation Partnership (TRIP), a collaboration of state and local partners, issued a request for information (RFI) on CAVs and innovative transit systems, organized and hosted an expo on how to create a successful pilot program with public, private, and academic partners, and finally issued a request for proposals (RFP) for a public-private partnership to provide a pilot mobility service utilizing connected and highly automated and/or autonomous vehicles to connect Providence's downtown to the Woonasquatucket Corridor and fill a transportation gap in an area of burgeoning development.

We accomplished that by building our own institutional capacity and knowledge through extensive research of the subject, collaboration with industry, academia, and other government entities, and built a partnership that extends beyond Rhode Island and studied some of the most universal impacts of these technologies. The TRIP Mobility Challenge became the Little Roady, a pilot project that looked to investigate certain key lines of inquiry related to the future role and impact of autonomous vehicles on our transportation system and network. Our goals and guiding principles related to:

- Safer transportation
- Sustainability, fuel reduction, reduced congestion
- Improved and equitable mobility
- Economic growth and a strong workforce
- Smart cities, data management, and privacy

We know that autonomous vehicles have the potential to save many lives as they may eliminate many of the human factors that cause a good portion of the traffic accidents today. In the short term, as we transition to this new mode of travel and test them, CAVs must be able to recognize, yield to, and share the roads with all users of the roadway.

Questions the pilot hoped to answer include what the challenges and opportunities are we facing when it comes to assessing liability and measuring the cost of risk as technology changes rapidly? What are the implications for the public sector (e.g., safety enforcement), for manufacturers, and for the automotive insurance industry as CAV and other innovative transport technologies emerge?

The arrival of CAVs, the wider acceptance of mobility as a service (MaaS), expansion of on-demand ride-sharing programs, and the increased move toward electrification will have significant impacts on many people in the transportation-sector workforce. At the same time that it impacts existing jobs, these changes will provide opportunities for growth through the creation of new types of jobs and increased access to workplaces. RIDOT chose to be proactive and understand to the greatest extent possible this impact, and position the state to take advantage of the new technology.

The TRIP Mobility Challenge and Little Roady set out to find answers to many of these questions, and while not all of them might have complete answers after nearly nine months of running the pilot program, we believe that we have learned valuable lessons that are being documented as part of this research report.

The pilot helped us learn from other people sharing their knowledge, and we are glad to be sharing what we have learned so far and the approach that we are taking by involving our transportation partners, customers, stakeholders, and private entities interested in researching these technologies.

Peter Alviti Jr., PE
Director
Rhode Island Department of Transportation

Acknowledgments

This project and the supporting research would not have been possible without the exceptional support received from several individuals and organizations, to which we are deeply indebted. From the inception to the completion of the project, RIDOT and the Research Team relied on consulting and advising with several individuals and organizations that freely shared their knowledge and expertise, allowing the Department to move forward with an ambitious project such as this without the use of any outside consultants.

RIDOT's Policy & Innovation Team and the Little Roady Research Team wish to acknowledge the contributions and support received from the following individuals and organizations, with their affiliations listed in relation to the time of the pilot. Because the list of individual contributors is far too great for proper credit, we apologize in advance for any unintentional omissions.

RIDOT

- Leadership: Peter Alviti Jr., P.E. Director, Loren Doyle, Chief Operating Officer
- Policy & Innovation Team: This project was led by RIDOT's Policy and Innovation Team, composed of Pamela Cotter, Julia Gold, Russ Holt, Shoshana Lew, Adrianna Morocco, Ken White, and Christos Xenophontos. While some of the members of the original "PIT Crew" have since left RIDOT, their contributions and those of the entire team have been invaluable to the success of this project.
- Leadership and employees of RIDOT's Communications Office, Maintenance Division, Office of Highway Safety, and Transit Planning Division for their assistance during the launch and operations of Little Roady
- Others at RIDOT at the time of the pilot: Meredith Brady and Thomas Queenan

Partners

- City of Providence: Mayor Jorge Elorza, Sabrina Solares-Hand, Martina L. Haggerty, Bonnie Nickerson, Tony Morabito, Nate Urso and the Public Works Department, and Commissioner Steven M. Paré and the Office of Public Safety
- Quonset Business Park (QBP): Steven J. King and Katherine Trapani
- RIDMV: Walter R. "Bud" Craddock, Administrator, Brad Booth, Marcy Coleman, and Doug Staradumsky
- RIPTA: Scott Avedisian, Amy Pettine, Greg Nordin, Sarah Ingle, Tom Cute (Amalgamated Transit Union, Local 618) and the Paratransit Team, Drivers and Operations staff, who were instrumental in arranging for the Little Roady replacement service during the pandemic
- Research Team: 3x3, STAE, Bits & Atoms, and Brown University

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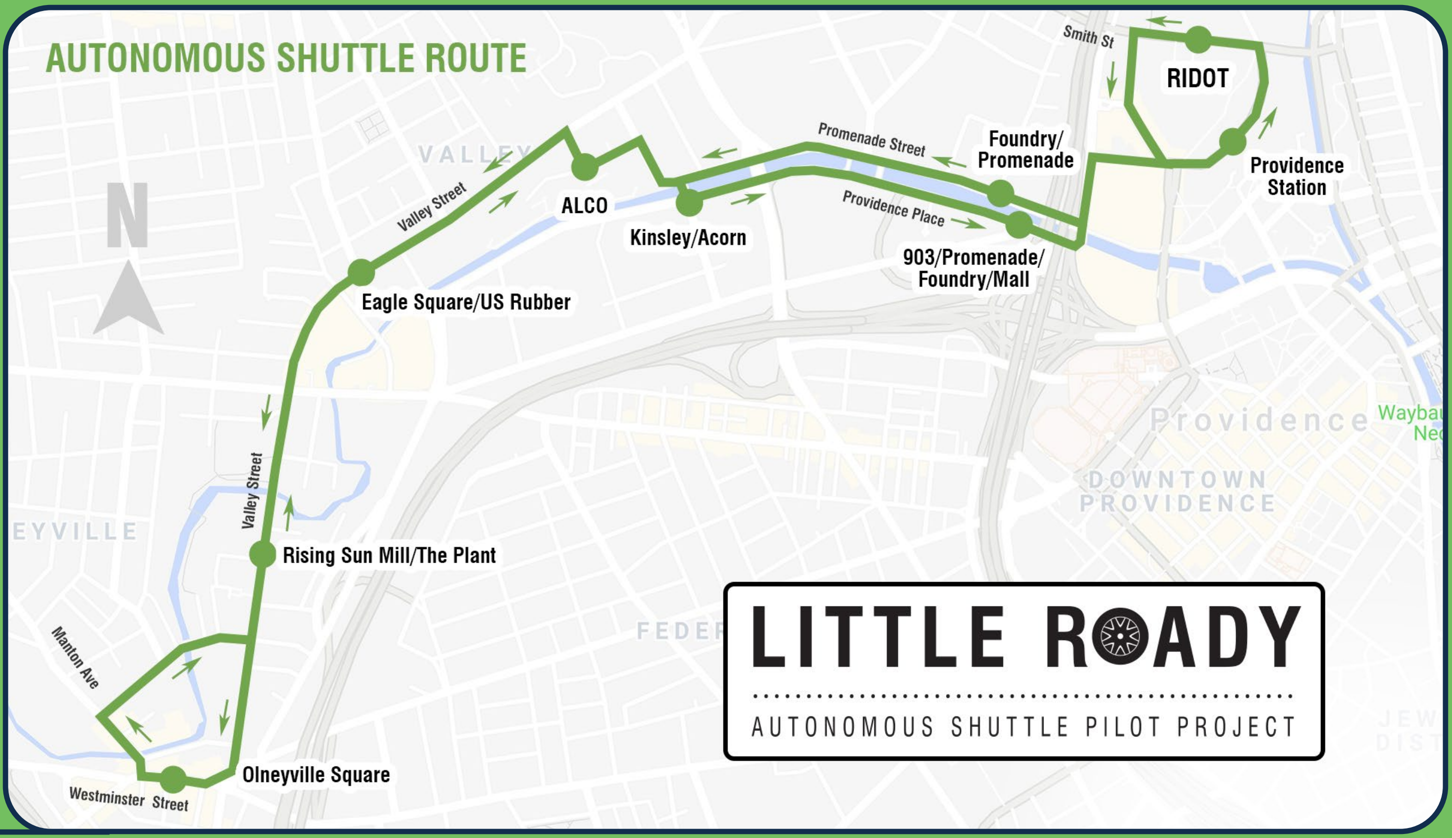
Executive Summary

The Little Roady Autonomous Vehicle (AV) shuttle pilot was coordinated by the Rhode Island Department of Transportation and consisted of a free daily shuttle service operated from May 2019 through June 2020 along a twelve-stop, 5.3-mile loop along the Woonasquatucket River Corridor in Rhode Island. The project stemmed from a vision among RIDOT leadership to focus on mobility-related opportunities offered by emerging and disruptive technologies such as autonomous vehicles.

As an example of an innovative public-private partnership model, key goals of the Little Roady project were to safely introduce and test AV technology in Rhode Island, provide meaningful first/last mile transportation linkages, create economic opportunities, accelerate innovation, and support and evaluate public user experiences related to the project. This document summarizes the history of the project overall and lessons learned from an associated research effort established with the goals of understanding: attitudes and perceptions surrounding AV technology, rider usage and engagement with the shuttle pilot, rider and transit worker pilot experiences, and overall pilot performance and technology.



Key Methods

A research team composed of 3x3, Stae, researchers associated with Brown University, and the Star City Group was selected to gather and analyze data associated with the pilot, including the following:

- Neighborhood landscape assessment
- National survey (*N* = 1,000) and Rhode Island experimental survey (*N* = 500)
- Baseline and ongoing pilot rider and non-rider survey (*N* = 1,089)
- Field observations at shuttle stops (*N* = 349) and in shuttles (*N* = 434)
- Interviews with riders, non-riders, neighborhood stakeholders, fleet attendants, and supervisors (*N* = 64)
- Qualitative and quantitative monthly reporting from the AV operator
- Representational state transfer application programming interface (RESTful API) shuttle service operational data (e.g., route geometry, ridership, vehicle performance, etc.)

Main Findings

AV pilot performance and ridership

- Ridership increased steadily until sudden service disruption following the emergence of COVID-19.
- Operational challenges plagued the pilot in early months, but reliability improved over time.
- AV mode reliability and use appeared to improve over the course of the pilot, but many questions remain due to limited data sharing from the shuttle operator.
- Incidents were infrequent, generally not serious, often unrelated to AV, yet difficult to interpret due to data sharing challenges.

Government and management

- Trialing AV technology as a form of transit in a complex urban setting demonstrates that the industry is not as ready may be indicated in media and by operators.
- With AV service providers operating in a black box, true costs to the public remain unknown.
- Diverging interests and perspectives call for close attention to how public-private partnerships are structured if AV transit deployments are to serve a public good, especially in relation to data sharing, uniformity, and transparency.

Workforce development and fleet experiences

- Little Roady fleet attendants brought to life many questions about changing roles and responsibilities among public transportation workers in the context of increasingly automated transit systems.
- Little Roady fleet attendants reflected positively on their jobs, and RIPTA transit workers appeared optimistic about AV technology, but questions about the future remain.
- Fleet attendants required ongoing training and incentives to increase use of AV mode.

Rider attitudes, perceptions, and experiences

- The public has a sophisticated perception of the convergence of issues associated with AVs and the mobility system, including convenience, technology, efficiency, privacy, and safety, among others.
- Many user experiences were very positive, but also not directly AV-related.
- AVs increase, not decrease, the importance of user-centered design of the transit system for the most marginalized riders.

Ridership

Ridership steadily increased until COVID-19-related operational disruption; RIPTA stepped in to operate in place of AV operator, May Mobility.

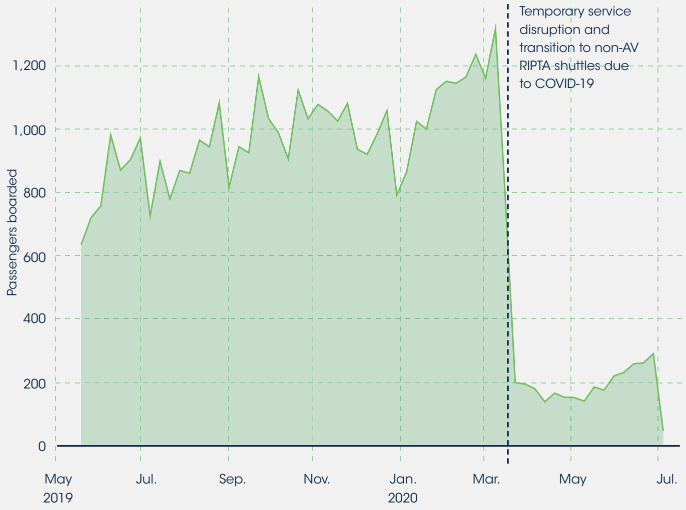


Figure i-1. Overall weekly ridership: AV and RIPTA shuttles (Total weekly passengers boarded) (p. 71)

Service headways

A spike in summertime headways reflects a confluence of logistical and reliability issues that initially impacted shuttle operations, but were later stabilized.

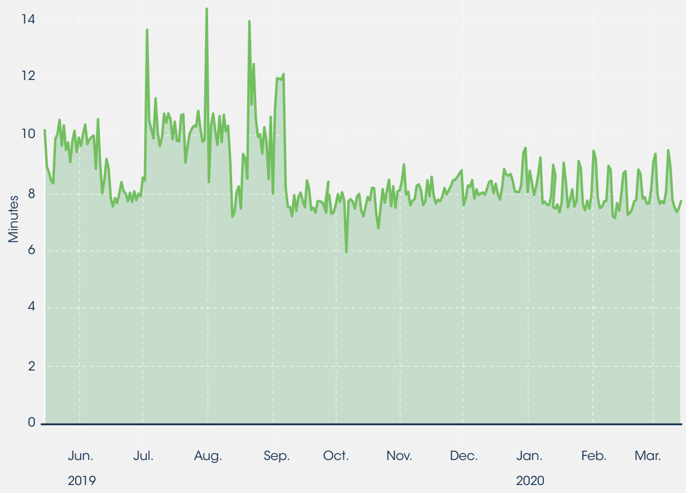


Figure i-2. AV shuttle daily average route-wide headways (May 2019–March 2020) (p. 75)

AV mode use and disconnects

Vendor-supplied AV mode heat maps indicate that AV mode use increased throughout the pilot, but lack of access to metrics limits confidence. Observed manual overrides demonstrate limitations related to technology and operator confidence.

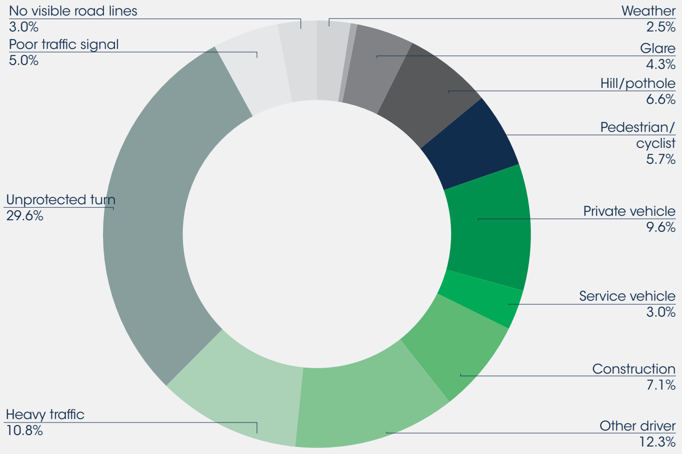


Figure i-3. Observed reasons for AV to manual mode shift (*N* = 434 observations, May 2019–March 2020) (p. 81)

AV perceptions

In a regional rider/non-rider survey, participants who reported previous direct AV experiences expressed higher interest in AV ridership (a non-causal relationship, but a potential indication of the value of real-world pilots).

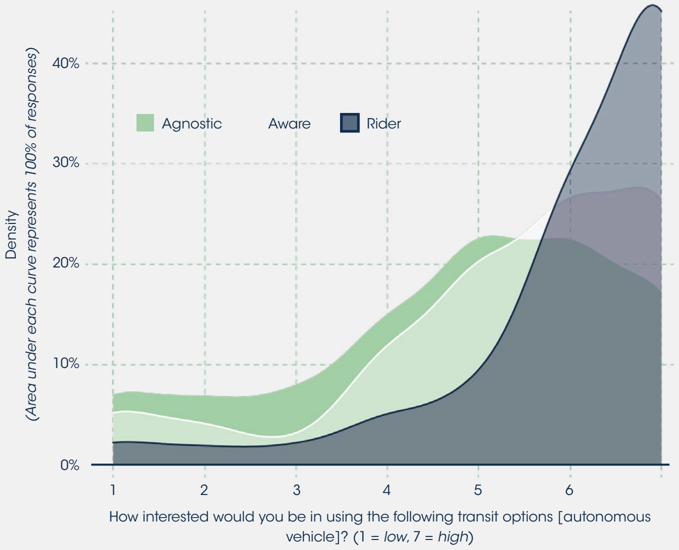


Figure i-4. Survey participant interest in riding in autonomous vehicles (by user type) (p. 58)

Time in AV mode

While use of AV mode reportedly increased throughout the pilot project, approximately 40% of half-route field observations were run entirely in manual mode, with average time spent in AV mode typically less than half of a given route duration.

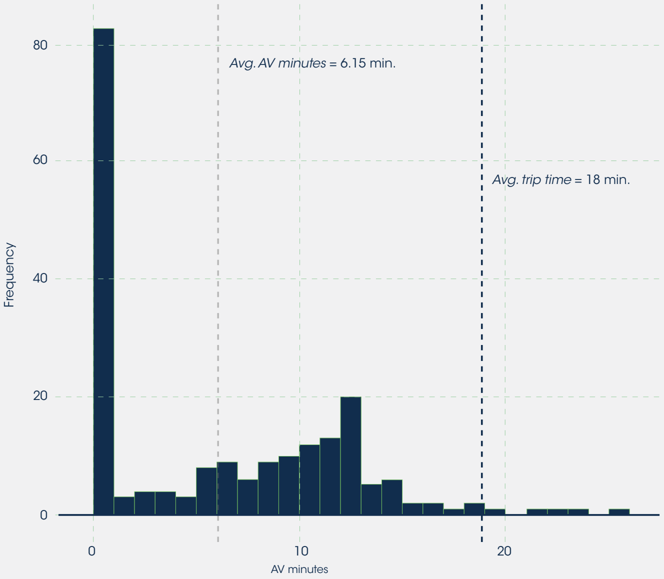


Figure i-5. Histogram of observed minutes in AV mode per one-way (half) route observation period, from RIDOT to Olneyville Square (*N* = 207 observations, May 2019–March 2020) (p. 82)

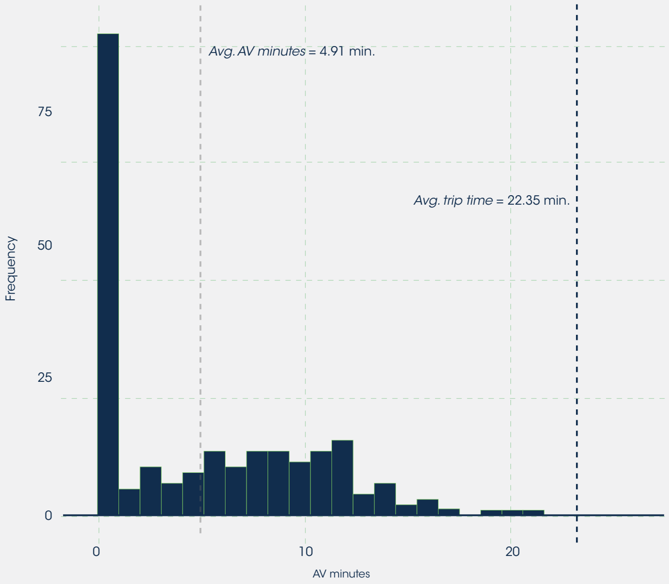


Figure i-6. Histogram of observed minutes in AV mode per one-way (half) route observation period, from Olneyville Square to RIDOT (*N* = 217 observations, May 2019–March 2020) (p. 82)

Opportunities

Governance and industry partnerships

- The public sector can lead the AV industry by setting the precedent for the market to follow.
- Engage in early-stage negotiations to set up mutually-beneficial public-private partnerships that ensure the public partner has desired data access and appropriate level of operational control.
- Make space for early and ongoing multi-stakeholder engagement.
- Proactively approach safety, ethics, algorithms, and automated decisions.
- Collaborate with workforce leaders on the changing role of the transit workforce in the context of an increasingly automated future.

AV-related or -enabled opportunities; explore the following:

- Connected vehicle to infrastructure technology
- Integrated multimodal networks and first/last mile solutions
- The “AV black box” and data ownership
- Flexible and resilient forms of microtransit
- AV-augmented public transit
- Pricing models that mitigate negative externalities

Advice for AV-transit pilots in other cities

- Design pilots from a bird’s eye view to answer questions surrounding planning, policy, and regulatory implications of AV transit technology.
- Align on success metrics with service partners early and create a data schema in collaboration with stakeholders, third party researchers, and data partners.
- Develop hiring requirements and conduct holistic training for operators.
- Pursue funding that allows for parallel and independent research.
- Prioritize informative and targeted marketing and communications coupled with a General Transit Feed Specification (GTFS) feed for service discoverability.
- Make better use of depots by taking advantage of the highly controlled settings.

Long-term planning and policy considerations

- AVs can play an integral role in a multi-modal mobility network by providing first and last-mile solutions to address equity in transportation access.
- Advance accessibility in vehicle design.
- Plan infrastructure and connect AVs with other smart city initiatives for seamless AV transit deployments that optimize for positive externalities.
- Begin planning and building infrastructure for fleet transformation through targeted research. ●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Key Terms

Automated driving system (ADS)	The combination of hardware and software that is collectively capable of performing on a sustained basis all of the real-time operational and tactical functions required to operate a vehicle in on-road traffic (e.g., steering, throttle, braking, etc.) without driver input. Automated driving systems are distinct from driver support features that are associated with less comprehensive systems that require drivers to supervise and perform core functions (see: Driving Automation System [DAS]).[1]
Autonomous vehicle (AV), autonomous mode	A vehicle that is equipped with a combination of driving automation system (DAS) components. It is notable that SAE recommends against use of this term due lack of unified definitions.[1] However, the term autonomous vehicle (and the associated autonomous and manual modes of operation) is used in this report as a shorthand for the presence and use of DAS-related aspects of the shuttle pilot vehicles in alignment with practices and terminology of the shuttle pilot operator.
Connected vehicle (CV)	A vehicle that uses technology to communicate with other vehicles, signals, signs, other road systems, or cloud-based systems. Typical applications are used to improve traffic safety and flow.
Dedicated Short Range Communications (DSRC)	A form of secure communications that typically support intelligent transport systems. Key components of DSRC are roadside units (RSUs) and on board units (OBUs), which include transceivers, and as such send and receive traffic-related information.[2] DSRCs are one- or two-way wireless communication channels and corresponding protocols and standards intended for automotive applications for vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication.
Driving automation system (DAS)	A vehicle system that performs part or all of the dynamic driving tasks (DDT) on a sustained basis. As such, this term applies to all systems that incorporate any degree of automation, even including those that provide partial driver support as opposed to more comprehensive automation.
Georeferencing	A system that allows for the internal coordinate system of a digital asset (e.g., map, aerial photo, etc.) to be related to a ground system of geographic coordinate so every point on the asset can be located on the Earth's surface.

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[1] SAE International. (2021). J3016: *Surface vehicle recommended practice: (R) Taxonomy and definitions for terms related to driving automation systems for on-road motor vehicles.*

[2] United States Department of Transportation. (n.d.). *Intelligent Transportation Systems—Dedicated Short Range Communications (DSRC).* Retrieved February 22, 2021, from https://www.its.dot.gov/communications/media/1probe.htm

Light detection and ranging (LiDAR)	A technology that typically uses pulsed laser waves to measure distances, and thereby the features and configuration of objects in space.
Operational Design Domain (ODD)	The specific operating conditions in which a driving automation system is designed to properly operate, including but not limited to environmental (e.g., weather), geographical, and time-of-day restrictions, as well as the requisite presence or absence of certain traffic or roadway characteristics (e.g. roadway types, speed range), and other domain constraints.
Roadside unit (RSU)	A component of DSRC that is typically mounted along a road or a pedestrian pathway and includes a transceiver that broadcasts data to, or exchanges data with, other components of connected vehicle technology network. RSUs enhance situational awareness for connected vehicles (CVs) by sharing information about a driving environment collected via cameras and sensors.
Semantic map	A component of the overall mapping system that automated vehicles rely on to function. They often include a myriad of relevant 2D and 3D objects, including lane boundaries, intersections, traffic signs, and signals.

1.0

Introduction

Nearly a century ago, America's first look at a self-driving vehicle was a spectacle of wonder and foreboding. American Wonder, a sedan modified for remote control by radio appeared to drive itself down Broadway in New York City "as if a phantom hand were at the wheel" (The New York Times, 1925, para. 2). Today, technology giants and automakers are locked in a globe-spanning race to finally and fully bring to life this age-old dream.

Introduction

The technology these entities are trying to perfect dates to the 1960s, when researchers first began using computers to simulate human vision by using a process that involves scanning images captured by video cameras to identify objects and other environmental conditions as inputs to guide automated driving decisions. Researchers at Stanford University attempted to teach robots how to drive across a laboratory and beyond (Kubota, 2019).

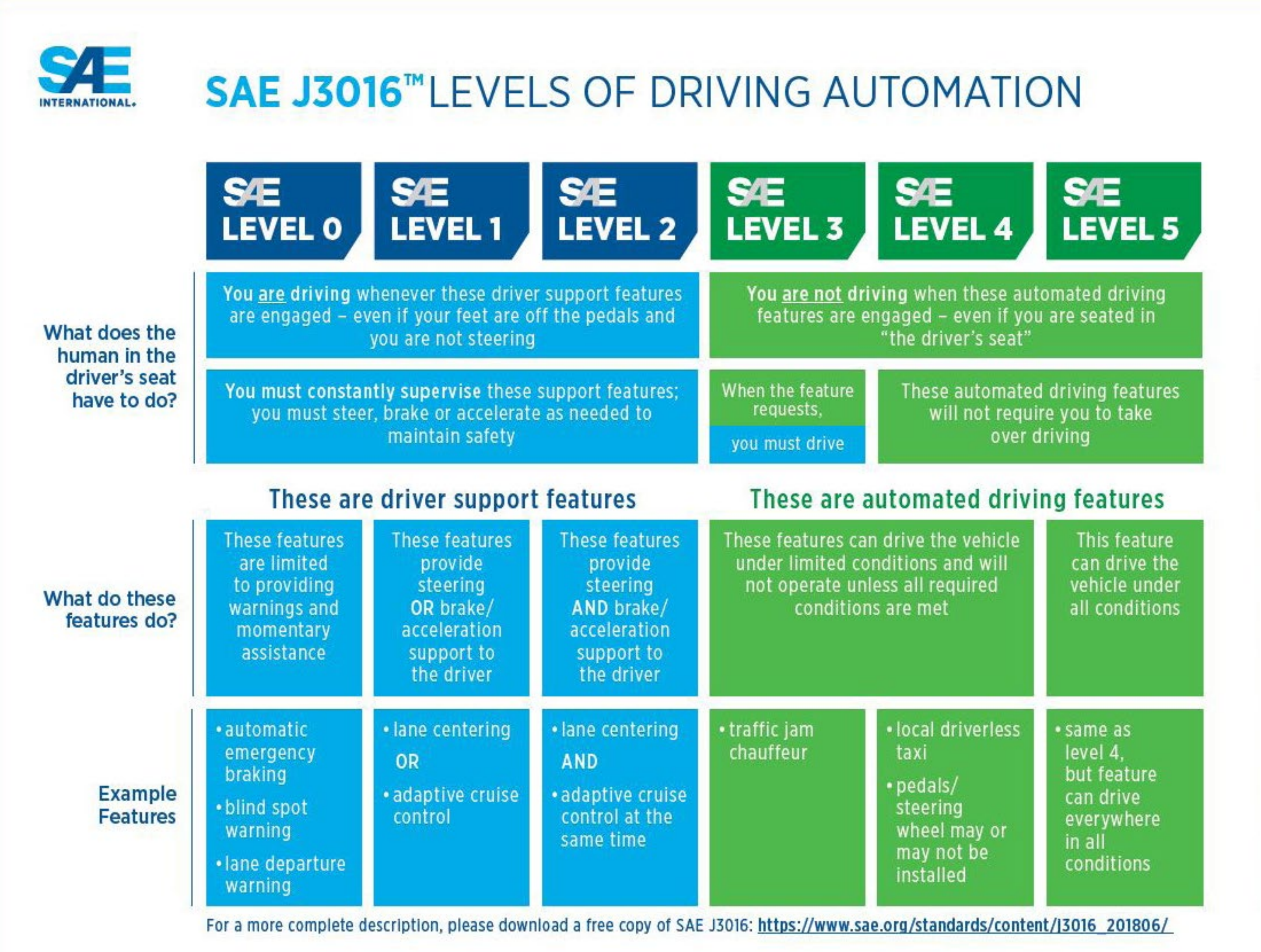
During the 1970s and 1980s, researchers in Japan and Germany harnessed more portable, yet more powerful, computers to build and successfully road test vans driving by what came to be called *computer vision* on the open road (Delcker, 2018; Weber, 2014). With growing interest from the United States government, from 2004 to 2007, a series of high-tech challenges demonstrated the potential for fully autonomous vehicles navigating across rugged wilderness areas and simulated suburbs alike (Thrun et al., 2006). From those races, a new pool of talent and a road map for five levels of automation emerged, spanning the gamut from fully human-driven (*level 0*) to fully computer-controlled (*level 5*) (Figure 1-1).

The basis for all this research and testing was the anticipation of the eventual replacement and retrofitting of the world's existing fleet of automobiles with autonomous counterparts. Google seemed poised to bet on automated cars as the next big computing platform, in much the same way it had bet on Android and mobile devices (National Highway Traffic Safety Administration, 2017). Automakers the world over were spurred to accelerate their own plans for automation. Globally, some $80 billion surged into automated driving tech between 2016 and 2017 alone, but truly autonomous cars failed to materialize. Tesla, the most aggressive proponent, pushed back its release date for highly automated models (Kerry & Karsten, 2017) and General Motors' rollout was even more conservative. When the first unstaffed autonomous passenger car entered service—a Chrysler Pacifica minivan—did so in 2020, it was in the service of Waymo, Google's ride-hail spinoff (Krafcik, 2020). A full decade had passed since the search giant's self-driving car project began..

1.1. Automation's Impact: From General-Purpose to Specialized Vehicles

Waymo's automated ride-hailing service rollout highlighted a crucial detour in the development of driverless vehicles. Even as automakers and tech giants alike struggled to bring general-purpose automated vehicles (AVs) to market, specialized vehicles designed for more limited settings and uses were speeding to market. By the time Waymo started picking up passengers

Figure 1-1. Society of Automotive Engineers five levels of automation (Shuttleworth, 2019)



SAE J3016™ LEVELS OF DRIVING AUTOMATION

	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	**You are driving** whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering			**You are not driving** when these automated driving features are engaged – even if you are seated in "the driver's seat"		
	You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety			When the feature requests, you must drive	These automated driving features will not require you to take over driving	
	These are driver support features			These are automated driving features		
What do these features do?	These features are limited to providing warnings and momentary assistance	These features provide steering OR brake/ acceleration support to the driver	These features provide steering AND brake/ acceleration support to the driver	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met		This feature can drive the vehicle under all conditions
Example Features	• automatic emergency braking • blind spot warning • lane departure warning	• lane centering OR • adaptive cruise control	• lane centering AND • adaptive cruise control at the same time	• traffic jam chauffeur	• local driverless taxi • pedals/ steering wheel may or may not be installed	• same as level 4, but feature can drive everywhere in all conditions

For a more complete description, please download a free copy of SAE J3016: https://www.sae.org/standards/content/J3016_201806/

in the Phoenix area, commercial AVs had already been at work for years in strip mines and cornfields all over the world. So great was this variety that by 2019, the University of Michigan's Robot Survey identified over 80 different types of commercially available AVs for use in urban areas, including delivery vans and buggies, street sweepers, and security droids (University of Michigan Civic Futures Thesis Group, 2019).

Three trends drove the specialization of AVs: (a) new mobility patterns, (b) changes in manufacturing, and (c) electrification (Townsend, 2020). First, the dispersal of origins and destinations, and more complex patterns of trip chaining have disrupted traditional patterns of commuting (Pisarski, 2007). While some of these shifts have favored automobiles over fixed transit, they have also created opportunities for other non-automobile modes such as walking and biking, thereby creating market opportunities for new vehicle types.

Second, new manufacturing techniques such as 3D printing and new supply chains make it economical for smaller companies to produce high-quality vehicles faster and with shorter and smaller production runs (Crunchbase, n.d.). This is creating greater variety and competition in the long tail of the vehicle industry.

Finally, electrification and automation are symbiotic technologies that work well in combination. Electrification paves the way for automation by extending computer control throughout a vehicle's entire steering and propulsion system, creating points for software-based innovation (Mitchell et al., 2010). Automated driving is also a boon to electric vehicles by making it easy to coordinate recharging schedules and locations, which spreads the strain on power grids and allows heavier use of renewable generation.

1.2. A First/Last-Mile Solution Emerges: Automated Shuttles

One specialized type of AV has spread faster and more widely than any other: the automated shuttle. To date, hundreds of cities around the world have engaged in pilots, demonstrations, and full-scale deployments of first/last mile transit services using these eight- to 12-passenger self-driving vehicles. All trace their lineage to a bold and pioneering experiment backed by the European Union in 2014. While Google's engineers were going the other way, scaling down technology tested in a Toyota Prius for a cute, custom-built 2-seater, dubbed the "Firefly," the EU project, CityMobil2, sought to build a city-friendly alternative to the Google smart car.

Among a series of demonstrations across the continent, the Greek city of Trikala played host to a three-month demonstration, the project's biggest test to date. Six shuttles snaked along a 1.5- mile route linking the city's historic quarter and its central business district (CityMobil2, n.d.). Most residents of Trikala embraced the technology. More than 12,000 people rode the six shuttles on nearly 1,500 trips over a three-month period. By the pilot's end, the initially suspicious Greeks had dispelled superstitious stereotypes with ease. Follow-up surveys showed that they were more accepting of the technology than were townspeople in France and Finland, where similar prototypes were later tested (City-Mobil2, 2016).

CityMobil2 sparked a global land rush as the two firms that supplied vehicles for the Trikala trial and those that followed, EasyMile and Navya, set off on a worldwide race to enlist cities to showcase the new technology (Bloomberg Aspen Initiative on Cities and Autonomous Vehicles, n.d.-b). In 2016 and 2017, automated shuttles crawled along the waterfront in Perth, Australia; through the central business district of Taipei; and up and down the Las Vegas Strip among dozens of other locations.

By the end of 2017, EasyMile claimed to have ferried more than 1.5 million passengers across some 20 countries (National League of Cities, n.d.). The following year, Navya sold more than 100 Arma vehicles and went public on the Euronext exchange. Both companies landed long-term financing. Navya partnered up with Keolis, the operating subsidiary of France's national railway, for a $33 million stake. Meanwhile, EasyMile raised $16.5 million from Alstom, maker of the French TGV bullet train (Navya, 2018).

In the United States, this initial success spurred others to jump in with new ideas and new innovations. Local Motors, which had pioneered the idea of crowd-sourced design of regionally-specific, small-batch cars, launched production of the Olli, which was 3D printed at the massive facility run by Oak Ridge National Laboratory in Knoxville, Tennessee (Bloomberg Aspen Initiative on Cities and Autonomous Vehicles, n.d.-a).

University of Michigan spinoff May Mobility made its debut at accelerator Y Combinator's demo day in 2017, drawing on a team whose roots traced back to those Pentagon-sponsored driverless tech contests a decade earlier. Rather than designing vehicles, May Mobility focused on software, touting its signature product, the Multi-Policy Decision Making algorithm (Wiggers, 2020).

Today, automated taxis still have to prove their worth. Despite industry claims, self-driving passenger cars are still a few years from market. However, automated shuttles have demonstrated a practical approach to deploying automated vehicle technology, and have secured a place in the future of transit. ●

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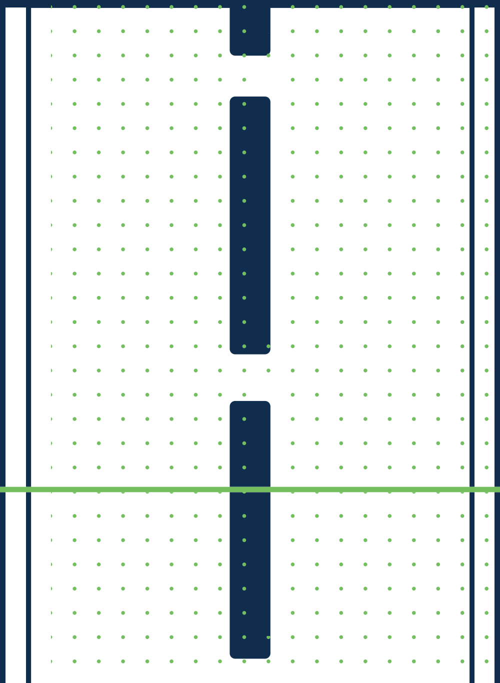
2.0

Project Background

The Little Roady project idea stemmed from the new RIDOT leadership's vision to develop a 10-year plan in 2015. The 10-year plan aimed to recognize and plan for the foreseeable changes to the transportation system and emerging policy trends. Internal research and discussions pinpointed the opportunities that emerging and disruptive technologies can offer for mobility, including better safety, accessibility, economic growth, health, and well-being benefits for the public, as well as reduced negative environmental impacts.



Project Background

2.1. Project Timeline

With the vision for an urban automation future laid out in the 10-year planning report, RIDOT initiated a multi-agency, two-year-long process in 2017 to develop partnerships for different smart city initiatives and set the groundwork for launching a pilot in 2019 (Federal Highway Administration, 2019). Key milestones and objectives of the two-year-long process are outlined in Table 2-1.

Table 2-1. Little Roady timeline

2017	
April	RIDOT hosted the International Mini-Summit on Connected and Automated Vehicles (CAVs) in Providence. Experts from PIARC (World Road Association) presented work being done in their countries, and RIDOT facilitated a focus group called the Policy and Innovation team.
June	RIDOT released the Request for Information (RFI) for CAVs and innovative transit systems.
July	Partners established The Rhode Island Transportation Innovation Partnership (TRIP).
September	TRIP hosted a CAV Expo at the New England Institution of Technology campus. The expo included panel discussions on opportunities for partnerships, infrastructure planning for CAVs, workforce development, environmental impacts, safety, mobility-as-a-service, and more. Site visits were conducted in Providence, Pawtucket, Central Falls, Quonset, and the University of Rhode Island (URI).
October	RIDOT closed and reviewed the RFI for the autonomous vehicle service pilot.
December	RIDOT formed a joint research forum with the University of Rhode Island, Transportation Innovation Partnership (TRIP): Leading the Way for Research.
2018	
April	RIDOT released the TRIP mobility challenge to seek an AV vendor.
November	A policy scrum session was organized by the Taubman Center for State and Local Government at the Harvard Kennedy School.
December	RIDOT announced May Mobility as the grantee of the TRIP Mobility Challenge.
2019	
January	RIDOT released the Request for Proposals for Community Survey.
February	Testing and set-up were conducted for the Little Roady shuttle at the Quonset Business Park.
May	RIDOT launched the Little Roady Shuttle & Community Survey.
2020	
March	May Mobility suspended Little Roady shuttle service, citing concerns due to COVID-19. Shuttle service resumed, operated by RIPTA.
June	RIPTA service ended.

2.1.1. Mini-Summit on CAVs

The multi-agency process began in April 2017 when RIDOT used the opportunity of hosting the members of PIARC's (World Road Association) Technical Committee TC A.1 to facilitate an international mini-summit on connected and autonomous vehicles (CAVs). The summit enabled RIDOT staff to understand what other domestic and international cities were doing to address CAVs while planning and developing transportation projects for the next decade.

2.1.2. Request for Information

Learnings from the Mini-Summit were recorded and helped inform a Request for Information (RFI) titled Connected and Autonomous Vehicles and Other Innovative Transport System Technologies Framework for Implementation and Integration (Rhode Island Department of Administration, 2017).

The RFI was released in June 2017 to solicit informational proposals from qualified vendors with planning, legislative, administrative, and/or technological experience with CAVs and/or other innovative technologies. RIDOT's goal was to support the facilitation and adoption of CAV in the City of Providence and gather ideas related to opportunities for public and private sector partnership, capital planning and execution process, regional safety programs, environmental impacts of autonomy, legislative and regulatory gaps, and workforce and professional training needs.

2.1.3. Rhode Island Transportation Innovation Partnership

Soon after the release of the RFI, RIDOT launched the Rhode Island Transportation Innovation Partnership (TRIP) in July 2017. The intent of the partnership was to bring together state and local partners to conduct research and explore new technologies and mobility solutions. The partnership was created to complement RIDOT's Rhode Works asset management program and involved agencies such as Rhode Island Department of Transportation, City of Providence (City of Providence Chief of Staff, Planning Department, and Department of Public Works), the Rhode Island Division of Motor Vehicles, the Rhode Island Division of Public Utilities and Carriers, key Rhode Island and Providence safety officials, the Quonset Development Corporation, and the Federal Highway Administration.

TRIP provided a mechanism and structure for RIDOT and Rhode Island to explore new transportation technologies, build a platform for trying out new innovations, and have a structure for education, inquiry, and dialogue among state partners.

> *TRIP provided a mechanism and structure for RIDOT and Rhode Island to explore new transportation technologies, build a platform for trying out new innovations, and have a structure for education, inquiry, and dialogue among state partners.*

TRIP Goals

With the goal of increasing access to sustainable, safe, reliable, and efficient mobility options and facilitate an encouraging environment for the private sector to develop new transport technologies in a responsible way, TRIP strategized opportunities for public-private partnerships and innovation by bringing policymakers and practitioners together including public agencies, private sector industries, universities, and workforce development centers. The desired impacts of the TRIP partnership were built from the thematic areas listed in the RFI and included (Rhode Island Department of Transportation, n.d.):

Safer transportation

This included the long-term goal of reducing traffic fatalities by eliminating human errors and factors that contribute to incidents through the use of fully autonomous vehicles.

Sustainability

The integration of AV technology achieving reductions in fuel use and associated carbon emissions with benefits for human health and the environment. This included a focus on the use of fuel-saving technology as well as considerations of vehicles, routes, and service models with the potential to minimize congestion and transportation footprints while achieving efficient travel options that are responsive to consumer needs and preferences.

Equitable mobility

Integration of new technology that seeks to serve a nimble system and adapt to the needs of a broad rider base, accommodating a diverse set of needs, reflective of the people of Rhode Island.

Economy and workforce

Changes in technology, including autonomous features, that have the potential to alter job opportunities in areas ranging from manufacturing to service to fleet operations. In addition, supporting training at the state level for new career pathways that help offset any disruptions, encourage new investment, and expand opportunities for the workforce.

Smart cities

Infrastructure that serves as a platform for information-gathering and sharing to improve systems, expand efficiencies, and allow for connectivity. This included framing data-sharing agreements to bring benefits to both public sector agencies and private companies, while protecting the privacy of individual users.

2.1.4. Rhode Island Transportation Innovation Partnership Expo

In September 2017, an Expo was conducted by TRIP on Connected and Autonomous Vehicles (CAV) and other innovative transportation systems technology at the New England Institute of Technology campus in East Greenwich, RI. The Expo positioned the City of Providence as a testing ground for emerging transportation technologies. The attendees were invited to tour the potential sites for Rhode Island's smart corridors and engaged in multiple panel discussions on pertinent themes such as infrastructure planning, workshop changes, best practices, and more

The RFI was closed and reviewed in October 2017. RIDOT received 30 proposals for pilots from 28 private organizations on thematic areas of mobility, safety, CAV planning and facilitation, security, and environment. The private organizations represented transit planners, consultants, transit operators, software solutions providers, systems integrators, data solutions providers, and suppliers and manufacturers. RIDOT formed a joint research forum with the University of Rhode Island (URI) in December 2017 to conduct research and assess opportunities for partnerships with the organizations that responded to the RFI (Lew, 2017).

The RFI helped RIDOT to engage the private sector and provide insight into what the industry could offer. It helped frame the TRIP Mobility Challenge and subsequently the RFP with RIDOT balancing the information gleaned on emerging technologies through the RFI with the needs and research goals of TRIP. RIDOT sought to balance a willingness to engage, site considerations, relationships, and opportunities for optimized outcomes (i.e., ridership, public roads versus private, the potential for ample learning, etc.). The RFP was developed in a way that allowed for structure and clear goals, but considerable room for private partners to propose what they could provide and offer.

2.1.5. TRIP Mobility Challenge

With TRIP in place, the State of Rhode Island introduced the TRIP Mobility Challenge, calling for a pilot program to leverage highly automated vehicles, easy-access mobility platforms, and other emerging technologies to position Rhode Island at the forefront of mobility testing. Following a precursory RFI to elicit feedback from industry representatives, an RFP was issued in April 2018 for vendors to enter into a public-private partnership (PPP) with the State to pilot a high-tech, sustainable mobility program in alignment with smart transit and innovation district investment. The scope included implementing a multi-passenger mobility service utilizing connected and autonomous vehicles to connect Providence's downtown to the Woonasquatucket River Corridor, over an 18-month period (including testing) with the option to renew annually for two additional periods. The goals of the Mobility Challenge drew from the goals of TRIP and included safer transportation, sustainability, equal mobility, economic growth and workforce development, and growth of smart cities (State of Rhode Island, n.d.).

The desired outcomes of the TRIP Mobility Challenge were to:

- Recognize, yield to, and share the road with all users as the City transitions to a new mode of travel;
- Provide first/last mile linkages with other existing transportation modes and points of interest, such as the Massachusetts Bay Transportation Authority (MBTA) commuter rail and Amtrak train service at Providence Station (with connecting service to TF Green Airport), existing RIPTA bus services, bike and pedestrian routes, the Woonasquatucket River Corridor and Downtown;
- Provide a sustainable and equitable mobility solution that will connect residents in the Olneyville, Smith Hill, and Valley neighborhoods of Providence with job opportunities within the Woonasquatucket River Corridor;
- Create new economic opportunities across skill levels, including training for new career pathways that will help offset any disruptions that come from new technologies and foster new investment opportunities in the Corridor;
- Accelerate adoption of AV and other innovations in Rhode Island, in large part due to deployment of new vehicle-to-infrastructure (V2I) technologies and Wi-Fi capabilities;
- Promote development opportunities and accelerate innovation in Rhode Island;
- Evaluate and demonstrate, via qualitative survey and quantitative data collection efforts, the performance of the pilot within a dense urban area that is open to

public travel and under all-weather conditions;

- Gauge public user acceptance of and experience with using the pilot system.

The scope included implementing a transit-oriented multi-passenger pilot mobility service utilizing connected and highly automated or autonomous vehicles to connect Providence's Downtown to the Woonasquatucket River Corridor. The service had to meet all federal safety and American with Disabilities Act (ADA) standards and exceed Society of Automotive Engineers' (SAE) automation level three. The contract period was for 18 months, with the option to renew annually for two additional periods of one year each. The 18-month period included six months for accommodating testing phases ahead of a 12-month service window (Rhode Island Department of Transportation, 2018).

May Mobility, an Ann Arbor, Michigan-based developer of self-driving shuttles founded in 2017, was selected as the best-value responder and awarded the contract to provide the services. Prior to winning this award, May Mobility launched a private corporate service in Detroit in June 2018 and entered into agreements for public service routes in Detroit, Michigan and Columbus, Ohio (State of Rhode Island, 2018).

2.1.6. Harvard Kennedy School Policy Scrum

In November 2018, a policy scrum session akin to a 24-hour hackathon was organized by the Taubman Center for State and Local Government at the Harvard Kennedy School. The session focused on the following questions:

- How can AVs complement and help to improve transit?
- With the introduction of modern technologies, how can we envision the use and development of curbside and street-side infrastructure to best meet the needs of our communities?
- What are the outcomes of success important to each of the Mobility Challenge project partners? What research questions and methods can be applied to ensure we achieve our goals?

The participants included a diverse group of stakeholders from the public, private, and non-profit sectors including RIPTA, RIDOT, City of Providence, May Mobility, Brown University, Growth Smart Rhode Island, and New England Institute of Technology, among others.

One of the outcomes of the session was refinement of the TRIP Mobility Challenge, including finalization of the plan for evaluating projects under the TRIP initiative as well as development of a plan for data collection and tools. An additional key action that emerged was the need to identify the best methods to report information gathered to various stakeholders, including via community outreach (Harvard Kennedy School Taubman Center AV Policy Initiative Team, 2018). ●

The RFP was developed in a way that allowed for structure and clear goals, but considerable room for private partners to propose what they could provide and offer.

2.2. Service Overview

The Little Roady shuttle service began in 2019, and provided a free shuttle service on a five-mile, twelve-stop loop between Providence Station and Olneyville Square along the Woonasquatucket River Corridor. The route for the service was selected with partners for its focus on transportation equity. Criteria considered included a route underserved by transit, low-speed roads, key locations that could serve as trip generators, and neighborhoods already identified as part of an innovation district by the City of Providence.

The Woonasquatucket River Corridor, a rapidly growing area without existing RIPTA service, fit the criteria well and was chosen for the pilot project. The area had seen increasing residential, commercial, and non-profit investment but did not have public transit options and thus remained disconnected from Providence's Downtown.

The key goals of the Little Roady shuttle pilot project were to:

- introduce AV technology to Rhode Island in a safe and accessible environment;
- provide first/last mile linkages with other existing transportation modes and points of interest, such as the MBTA commuter rail and Amtrak train service at Providence Station, RIPTA bus services, and bike and pedestrian routes;
- provide a sustainable and equitable mobility solution that connects residents in the Olneyville, Smith Hill, and Valley neighborhoods of Providence with job opportunities along the route;
- create economic opportunities across skill levels, including training for new career pathways that will help offset any disruptions that come from new technologies and foster investment opportunities in Rhode Island;
- accelerate innovation in Rhode Island;
- evaluate and demonstrate, via qualitative survey and quantitative data collection, the performance of the pilot project; and
- gauge public user acceptance of and experience with using Little Roady.

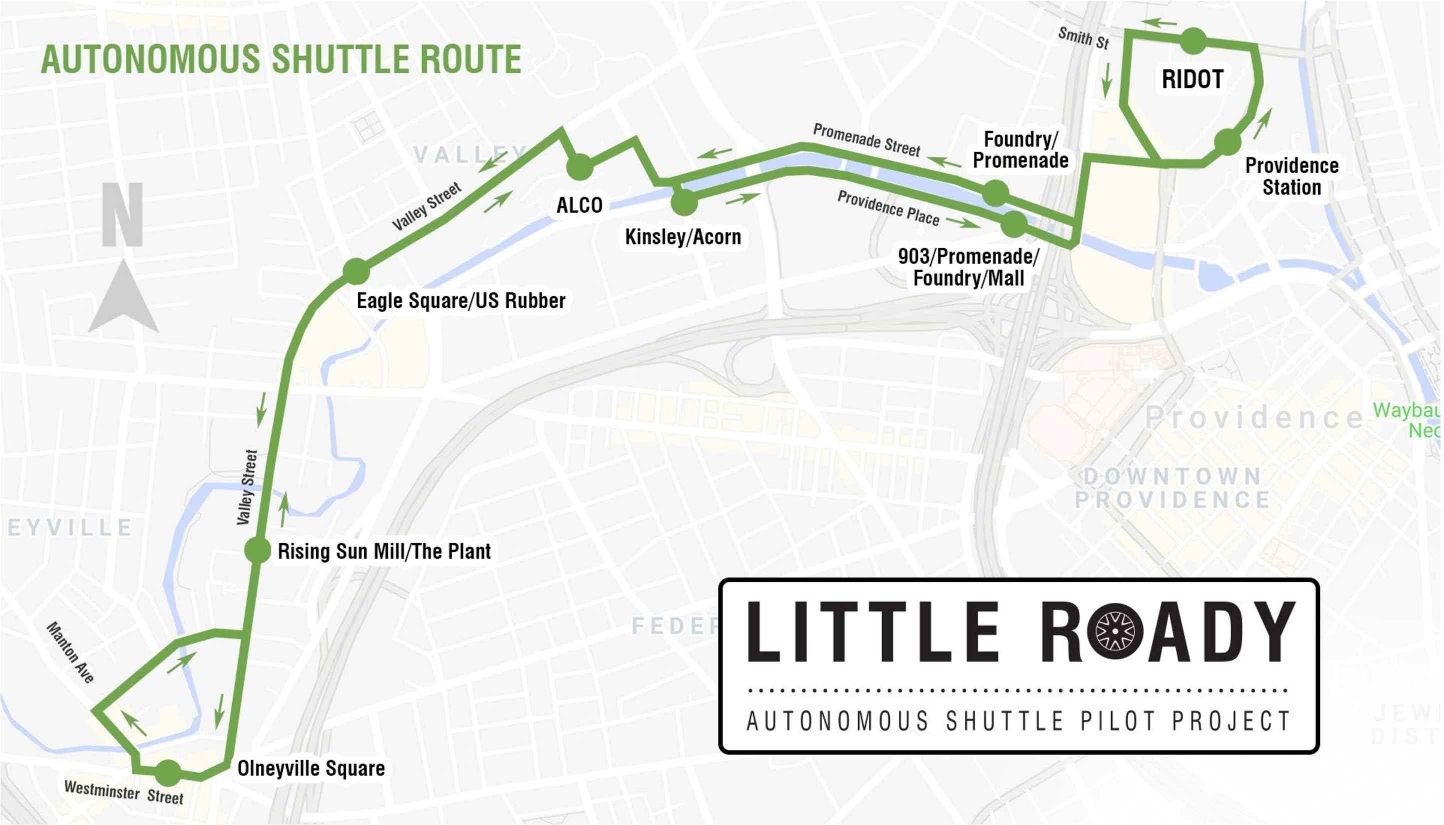
The service provided free rides to the public seven days a week, from 6:30 a.m. until 6:30 p.m. As per the Service Level Agreement between RIDOT and May Mobility, four to six vehicles were to operate at any given time. The electric vehicles were low speed, capable of driving up to 25 mph in manual mode and 20 mph in autonomous mode on the Polaris GEM e6 platform (NHTSA FMVSS 500 certified).

Each vehicle had five seats available to the public, a panoramic roof, built-in Wi-Fi, and large windows that roll up and down manually.

The vehicles were equipped with an array of proprietary sensors providing 360-degree coverage. Sensors and intelligent software helped the vehicle understand its location, in which direction to steer, as well as when to slow down, accelerate, or stop for something in its path.

The cost per rider was subsequently calculated per month, as indicated by May Mobility, following the launch of the service and ranged between $11.73 and $20.07, with an average cost per rider between May 2019 and March 2020 of $16.43 (May Mobility, 2020). The cost was calculated based on May Mobility's daily operational cost. See section 5.3.5. for a discussion on cost.

Figure 2-1. Little Roady route



2.2.1. Fleet attendants[1]

As previously described, there are six generally agreed upon levels of driving automation, ranging from no automation to full automation. The intent of the Little Roady AV shuttle associated with this pilot was to have level four driving features, in which the automated driving features of the vehicle would not require the driver to take control of the vehicle while the vehicle was operated within the operational design domain (ODD) of the pre-mapped route. As such, the Little Roady AV shuttle was only intended to require driver control in areas that were not georeferenced.

However, the shuttles were often driven as though features were at level two, as the complex nature of the route paired with technological limitations associated with dynamic routing led to constant deviation from the georeferenced route and required the presence of attendants to take over when a shuttle disengaged from autonomous mode. See section 4.3.4. for results related to AV mode performance.

At any given time during operations, three to six fleet attendants were on the road with two fleet attendants on break. The official responsibilities of fleet attendants included:

Operation and manual driving: The fleet attendants were responsible for the operation of the vehicles, including checking all the systems were in good working order and shifting the vehicles between autonomous and manual modes at key moments. They were also responsible for full manual operation of the vehicles if manual mode was enforced by technical or operational requirements from May Mobility.

Stewardship: Each fleet attendant was trained to be a friendly steward of the shuttle service, interacting with the passengers, promoting the service, reminding them to put their seatbelts on, and answering questions that passengers might have such as related to the technology, routes, and travel time.

Safety monitoring: The fleet attendants also took on the role of monitoring the safety of the vehicle, intervening in cases of unruly

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[1] The RFP for the project refers to this role as Operators, and a common but not universal practice in the industry is to refer to the role as attendants. May Mobility uses the term fleet attendant, so that approach is reflected throughout this report.

passengers or criminal activity to the extent they could do so safely.

Fleet attendants had State of Rhode Island operator licenses with chauffeur endorsements. They also needed to pass random toxicology and drug tests. Besides operations, driving, and safety monitoring instructors, the fleet attendants were provided ongoing additional training, including defensive driving training in August 2019. The course presents real-life driving situations and hazard recognition scenarios that help fleet attendants recognize their own personal driving tendencies and attitudes.

2.2.2. Service cost, phasing, and testing requirements

The cost of the project, including the research component, was approximately $1.2 million. RIDOT contributed $800,000 to the public-private partnership that included $300,000 of entirely federally funded research funds through the Federal Highway Administration and a $500,000 grant awarded by the Rhode Island Attorney General's Office as part of a settlement with Volkswagen for violating Rhode Island's laws prohibiting the sale and leasing of diesel vehicles equipped with illegal and undisclosed emissions control defeat device software. The service was planned to be executed over four phases:

The first phase included identification of vehicle and approval with a NHTSA certification; testing and approval in a relatively controlled environment within Quonset Business Park both during the day and at night, as well as in adverse weather conditions; stakeholder engagement; route finalization; and development of plans related to marketing, education, emergencies, and training. Phase one testing needed to encompass a minimum of 250 miles and the preparation of a safety report and recommendation for review and approval by RIDOT. May Mobility reported that the shuttles performed favorably across testing conditions, including 317 miles driven over 28 hours of testing in relation to lane keeping, obstacle avoidance, inclement weather, and response to pedestrians and other vehicles, among others (May Mobility, 2019a).

Phase two included the testing and configuration of the vehicles on the approved service route for a minimum of four weeks. The occupants of the vehicle at the time of testing were limited to the vendor, RIDOT staff, and TRIP partners personnel. The testing was completed during daylight hours and at night, as well as in adverse weather conditions. For adverse weather conditions, the testing was also repeated at Quonset Business Park. Additional Phase 2 testing was conducted post-live operations at the start of every new seasonal weather condition to ensure safety.

A safety report was prepared post-testing for review and approval by RIDOT with recommendations for improvements. May Mobility's phase two testing report, drawing upon 2,124 miles of driving in Providence and 1,689 miles of driving on the final route, described the testing phase as successful. However, a range of conditions under which the AV mode was overridden included heavy precipitation, heavy snow accumulation, proximity to aggressive driving behavior, unprotected turns, presence of emergency vehicles, and parked cars in stop locations (May Mobility, 2019b)

Phase three included meeting the legal requirements for operating and live operations. May Mobility obtained all the approvals, licenses, and permits required for operation, including the approval of the location. The Little Roady shuttle was made available for public showcase and stakeholder engagement as a part of an extended weekend before the launch of the service. Upon completion of all legal and testing requirements, May Mobility began live operations, the first two weeks of which were conducted under controlled conditions to make improvements based on the observations with approval of RIDOT.

Phase four was tentative and dependent on an assessment report related to the overall viability of the service and scalability to other districts within the City of Providence for year two operation.

2.2.3. Service suspension

On March 12, 2020, May Mobility informed RIDOT that they were suspending Little Roady AV shuttle service operations, citing concerns with the COVID-19 pandemic. The service was suspended following the end of the service on March 13, 2020. Following a two-day service suspension, the missing shuttle service was replaced by a conventional RIPTA shuttle service until the end of June 2020. ●

Project Background

2.3. Research Process Overview

In order to study the pilot and understand user sentiments, attitudes, and perceptions, a Call for Community Survey Proposals was released in January 2019 to conduct a community survey. RIDOT sought a research partner to develop and administer surveys for the pilot project and gather feedback from riders, non-riders, and the general public through surveys, interviews, and observational data. The goal was to prepare an assessment report as well as inform future policy and planning decisions related to the application of autonomous technology in Rhode Island. A research team composed of 3x3, Stae, researchers associated with Brown University, and the Star City Group was selected to analyze the data provided by May Mobility and collect and analyze qualitative and quantitative data about user perceptions, ridership, and impacts of the pilot. The next section discusses the research design in detail. ●

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3.0

Research Design

The pilot study was designed to understand how riders, non-riders, drivers, policymakers, and the general public respond to and are affected by the introduction of self-driving shuttles in a pilot AV program. The research objectives were to (a) inform Rhode Island's planning and policy development and regulation related to AVs, (b) contribute to a broader policy and scholarly discussion of how residents and regulators adapt to the introduction of new transportation technologies, and (c) understand and help improve the shuttle's user experience and service delivery. The project team took a mixed-methods approach to data collection and analysis for the pilot study that included surveys, interviews, and observational studies as means of collecting qualitative and quantitative data. The scope of the study was focused on the duration of the pilot service from May 2019 through June 2020. Learnings from the study were incrementally applied to adjust the service on an ongoing basis.

3.1. Research Questions

The scope of the pilot study was focused on four key themes: attitudes and perceptions, user behavior, service experience, and pilot performance.

- **Attitudes and perceptions:** What were the different perceptions that exist surrounding AV technology?
- **User behavior:** What was the nature of rider usage and engagement with the shuttle pilot?
- **Service experience:** What was the nature of user experience of the pilot from the perspectives of riders and transit workers?
- **Pilot performance:** How did the pilot technology and service perform? ●

Research Design

3.2. Lines of Inquiry

This project pursued the following lines of inquiry through multiple methodologies to answer the prior stated research objectives. The initial lines of inquiry guided the design of research methods and the analytical process, informed by refinement based on stakeholder feedback.

3.2.1. Neighborhood landscape assessment

A neighborhood landscape assessment was conducted for the Woonasquatucket River Corridor, the service area of the shuttle service. Indicators such as income, race and ethnic composition, and current transportation routes were assessed using publicly available economic and demographic data. Key informant interviews and document reviews were conducted to understand current transportation and planning initiatives in the area. The neighborhood landscape assessment provided an important contextual framework to understand the study area's social and economic landscape and inform the sampling strategy for surveys.

3.2.2. Attitudes and perceptions

To understand the nature of perceptions related AV technology held by community members, businesses, key stakeholders, and potential riders/non-riders, the research team sought to surface insights related to perceived impacts, acceptance, and awareness of AV technology.

- Potential impacts: What are the perceived positive and negative impacts of AV technology? Impact might refer to changes in safety, transit accessibility, traffic, social capital, employment, and infrastructure.
- Attitudes: How accepting are individuals of AV technology? Does it affect how individuals plan to use AVs or support the expansion of AV?
- Awareness: Does prior knowledge and awareness of the technology play a factor in perception and attitude towards AVs?

3.2.3. User behavior and pilot performance

To understand the utilization and performance of the shuttle pilot by riders and public transit workers, the research team evaluated shuttle usage considering factors such as demographics, accessibility, mode share, and origin/destination.

- Usage: What is the overall utilization of the pilot, and how does it fluctuate over time?
- Demographics and access: What are the demographic characteristics of users, and what patterns emerge? Factors such as income, race and ethnicity, and educational attainment were considered.
- Modal connection: How does the AV shuttle integrate with other forms of transportation available in the area?
- Origin/destination: Where do users of the shuttle travel from and to? What future routes would produce benefits?
- Safety: How safe was the pilot?

3.2.4. User experience

To understand the user experience of pilot shuttle riders and public transit workers, the research team developed research instruments to capture data related to satisfaction, safety, motivations for engagement, technology adoption, and user experience feedback. The user experience line of inquiry focused on feedback most relevant to RIDOT and the public sector aspects of user experience, such as route location and signage, as opposed to the vendor-specific feedback for May Mobility.

- Satisfaction/safety: What is the satisfaction with the shuttle pilot experience, and how safe do users feel before, during, and after riding the shuttle?
- Motivation: What factors motivated riders to take part in the AV shuttle?
- Adoption: Does participation in the AV pilot make individuals more likely to want to use and accept AVs in the future?
- Overall user experience: What is the overall experience riding the shuttle, and what could improve the experience? ●

3.3. Methods

3.3.1. Overall approach

There were three main areas of focus in the research design. The first aim was to estimate quantitatively via surveys the perspectives and attitudes of distinct stakeholder groups toward AVs. The second component of the research design proposed to characterize the experiences, ideas, concerns, and hopes of participants in the AV pilot through ongoing interviews, focus groups, and observations during the shuttle operation. Third, shuttle data from May Mobility was analyzed to assess performance of the pilot.

The sampling plan paralleled the gender, age, racial, educational, and transit characteristics of the population as a whole. The research team planned to have a representation of genders, ages, socio-economic status, locations, and education levels that mirrors that of Providence, Rhode Island.

A special emphasis was placed on residents living along the corridor route in the three neighborhoods, and the research team utilized outreach methods to reach those groups typically difficult to reach within the area, especially Spanish speakers. Distinct constituencies were kept in mind while designing surveys and other instruments, as well as during data analysis: riders versus non-riders, May Mobility representatives, and government representatives.

Rider/non-rider group: To better understand potential differences in perceptions in relation to distinct levels of experience with the Little Roady shuttle, in particular via the Little Roady rider/non-rider survey, participants were assigned to one of three groups for analysis: agnostic, aware, and rider, depending on responses to survey items related to their experiences with the Little Roady shuttle service.

- Agnostic: Participants who were not aware of Little Roady shuttle service.
- Aware: Participants who had heard about or seen the shuttle service but had not ridden it.
- Rider: Participants who had ridden the shuttle.

May Mobility group: This group included the fleet attendants, engineers, and supervisors who were involved in the operations of the Little Roady shuttle service.

Government representatives: This group included elected and career government officials who are charged with making and enforcing transportation and transit policies. These include individuals who oversee policies related to AVs at RIDOT, RIPTA, the Governor's Office, the General Assembly, DMV, key Rhode Island and Providence Safety officials, AAA, other governing bodies that have implemented AV technology in their localities, and the Insurance Division of the Department of Business Regulation.

3.3.2. Surveys

Surveys were used to capture sentiment, attitudes, and user experience feedback in relation to AV technology and the pilot shuttle at key moments during the pilot timeline. Multiple survey instruments were used to collect data and to reach all stakeholders in the mode with which they are most comfortable. Surveys were collected online through push and pull methods and in-person using time sampling based on known ridership patterns, and intercept survey tactics to capture immediate responses from transit workers, riders, and non-riders.

Little Roady rider/non-rider survey

The research team conducted an online and in-person survey with riders, non-riders, and the general public (N = 1,089) to capture sentiment, attitudes, and user experience towards AV technologies in general and the Little Roady shuttle service specifically during the pilot time.

National survey and Rhode Island experimental survey

The research team members at the Taubman Center for American Politics and Policy at Brown University, in partnership with research and analytics group YouGov, conducted two surveys to understand public perceptions of autonomous vehicles. One survey instrument reached a nationally representative sample of American adults (N = 1,000), and a second survey instrument reached a sample of Rhode Island residents (*N* = 500) representative of the state. The national survey sample was weighted based on gender, age, race, and education. Both surveys included a variety of modules exploring social, economic, and political questions, as well as a series of questions regarding participants' perspectives on autonomous vehicles. The principal purpose of the national survey was to understand why some people perceive autonomous vehicles more favorably than others, while the Rhode Island experimental survey explored the role of information framing on perceptions of AV technologies.

RIPTA driver experimental survey

The research team partnered with RIPTA to explore perceptions related to AV technologies among professional transit drivers (*N* = 24) and whether such perceptions change following hands-on experiences with AV shuttles.

Little Roady rider/non-rider survey sampling

In total, 1,140 participants responded to the Little Roady rider/non-rider survey. Of the 1,140 participants, 977 reported about their engagement level with the Little Roady shuttle service. Among participants, 31.7% had ridden the shuttle at least one time (*rider*), 23.8% had seen or heard about the shuttle service but never ridden (*aware*), whereas 41.5% were hearing about the shuttle for the first time through the survey (*agnostic*).

Little Roady rider/non-rider survey demographics: Survey respondents lived across a total of 247 ZIP Codes, including residents from Massachusetts (10.9%) and Connecticut (1.6%) that traveled to Providence frequently for work. A majority of the participants were Rhode Island residents (71.1%), and among them, a majority were Providence residents (72.1%). Among participants from Providence, the vast majority (81.6%) lived within the Little Roady service area.

The survey aimed to parallel the demographic characteristics of the population as a whole. According to the U.S. Census Bureau, females account for 51.6% of the population of the City of Providence (U.S. Census Bureau, n.d.). The survey had slightly more male respondents (42.8%) than female (38.1%). However, 18.8% of respondents chose not to disclose a gender identity, making it difficult to ascertain a complete understanding of gender representation.

The majority of the survey respondents had a Bachelor's degree (54.1%), with a small percentage of respondents indicating they did not complete high school (1.3%). Forty-five percent of respondents had a full-time job, and 11.8% reported having a part-time job. Students accounted for 16.0% of participants, and a small percentage of the respondents were retired (4.4%). Many respondents (37.6%) did not disclose their income group. For those who reported their income, the respondent sample shows representation across different income groups. See section 4.1.3. for comparative demographic data.

Table 3-1. Surveys

Methods	Sampling	Audience	Timeline
Pre-treatment baseline survey and ongoing rider/non-rider survey	112 + 977 = 1,089	Wider Providence	April–June 2019 May 2019–June 2020
National survey	1,000	Nationwide	October 2019
Rhode Island experimental survey	500	Rhode Island region	October 2019
RIPTA driver experiment	24	Professional Transit Drivers including RIPTA and May Mobility	July–August 2019

Figure 3-1. Survey participant engagement with the Little Roady AV Shuttle Pilot

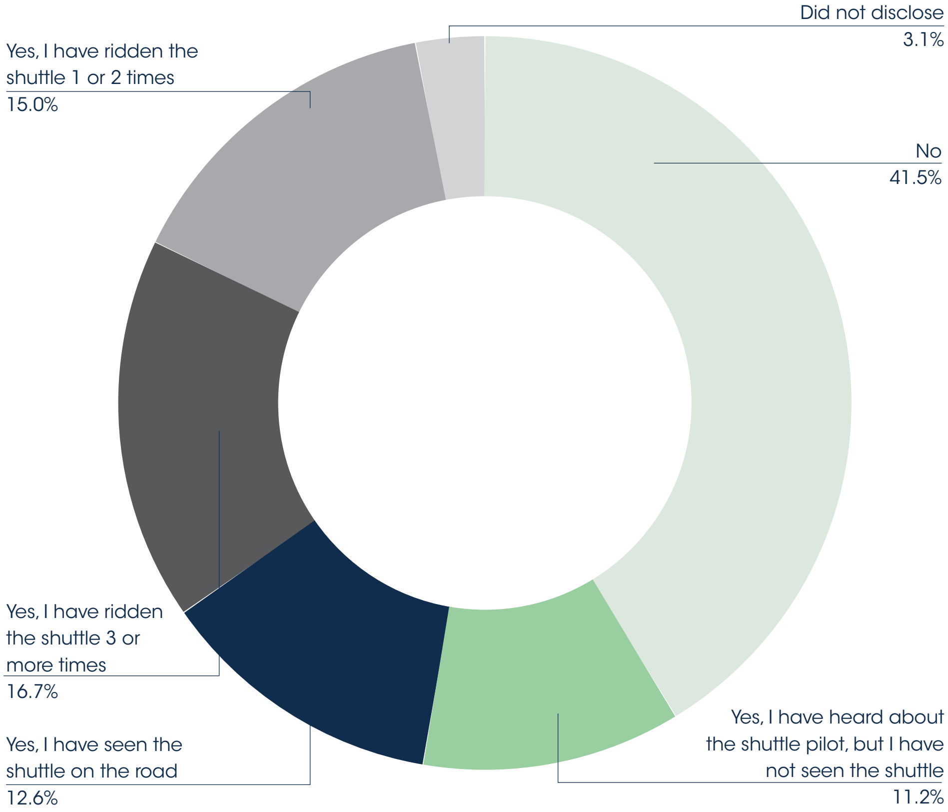


Figure 3-2. Survey participant residence (by ZIP Code)

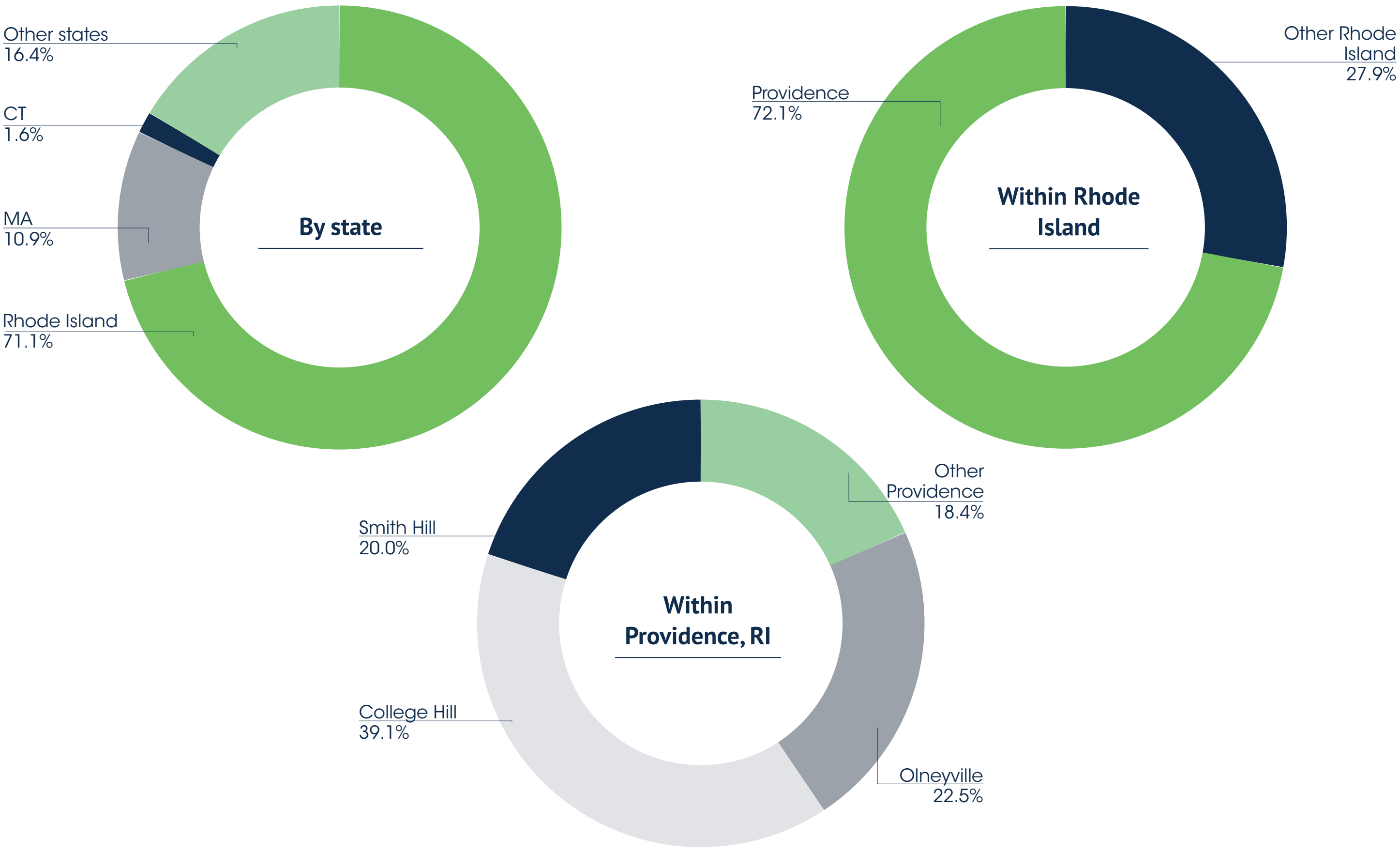


Figure 3-3. Survey participants by gender identity

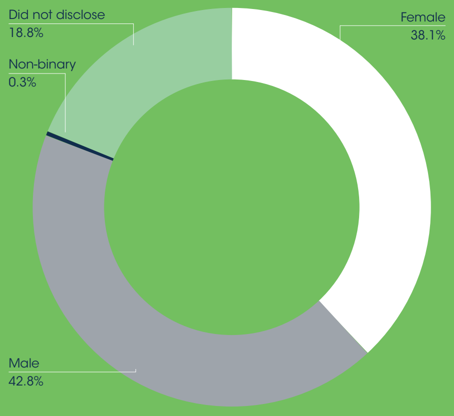


Figure 3-4. Survey participants by race

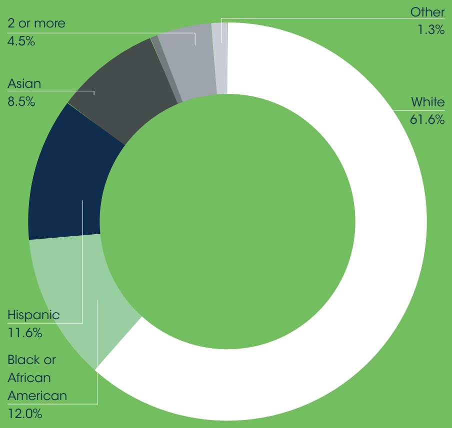


Figure 3-5. Survey participants by employment

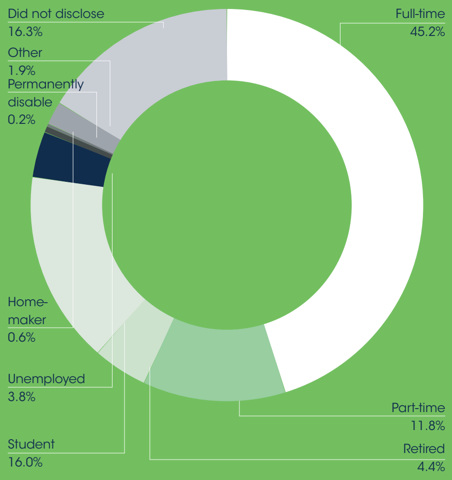


Figure 3-6. Survey participants by family annual income

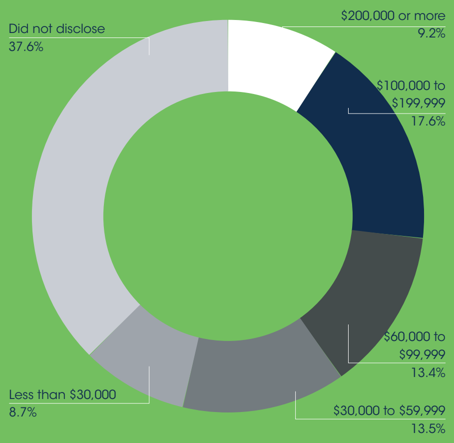


Figure 3-7. Survey participants by education

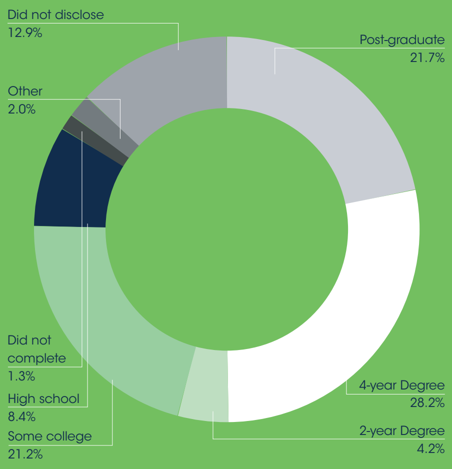


Figure 3-8. Survey participants' average daily commute time in the past month

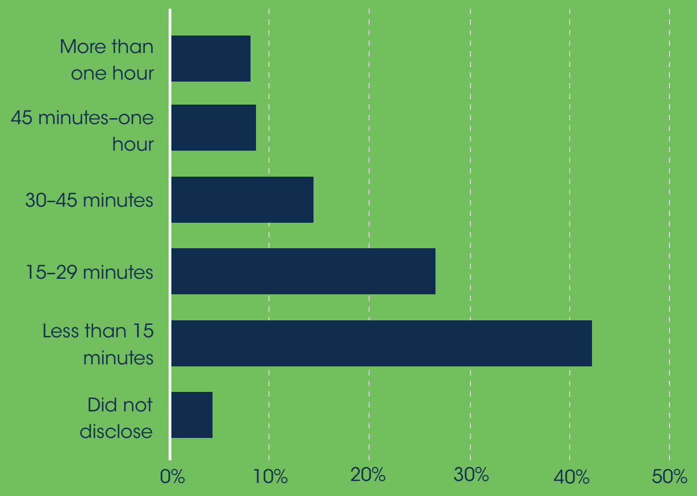
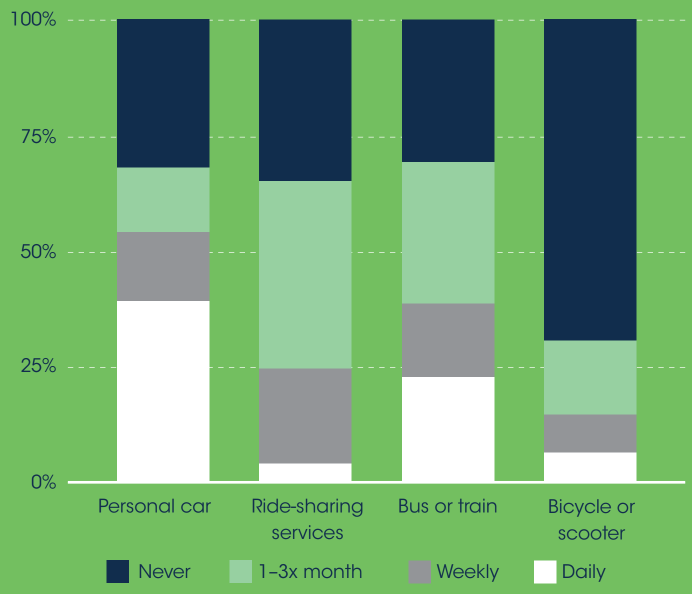


Figure 3-9. Survey participants' mode(s) of transit used in the past month



Respondents were asked about their morning commute ("In the past month, how long has your morning commute been on average?") as a means of assessing participant commute time. Forty-two percent of the respondents indicated their morning commute took less than 15 minutes, and 26.5% commuted between 15 and 29 minutes. Most riders of the Little Roady shuttle could be targeting a smaller distance in comparison with commuting patterns within greater Providence. Importantly, note that survey responses were captured before the emergence of the COVID-19 pandemic.

To compare with the transit mode use at the city level, respondents were asked about frequently used modes of transit. In response to question about transit use (*In the past month, how frequently have you used the following modes of transit?)* 40% of respondents indicated using a personal car every day, 22.9% reported using a bus or train daily, 6.5% reported using a bike or scooter every day, and 4.1% reported using a ride-sharing service every day. It is important to note that self-selection bias could have skewed respondents towards those more predisposed to taking public transit such as bus or train. Bicycling was not widely seen as a commuting mode among survey participants, but rather primarily as a recreational activity.

3.3.3. Interviews

Interviews served multiple purposes during the course of the research. First, before the detailed research instruments were finalized, key informant interviews with policymakers, TRIP partners, and key community members tested interpretations of proposed questions and helped the research team narrow on survey questions and evolve the research framework. Second, researchers conducted ongoing interviews with a sample of survey respondents to validate and add nuance to answered survey questions. These follow-up interviews prompted respondents to reflect on the details of their experience with AV and explore the motivations behind their numerical responses in the surveys

Along with the ongoing rider/non-rider interviews, the research team conducted interviews with May Mobility fleet attendants and supervisors throughout the course of the research to understand perceived impacts and to gain qualitative information from their perspectives. Questions for fleet attendants included similar questions from the rider/non-rider interviews in addition to driver-specific questions.

Semi-structured interviews with key stakeholders revealed ongoing initiatives, long-term goals, hopes, and concerns associated with the pilot. Simple and thoughtful questions and prompts guided and framed the conversation. Interviews spanned up to 45 minutes and were conducted in person and over the phone as needed.

Themes investigated included: (a) ongoing initiatives throughout the State, City, and corridor; (b) mobility gaps throughout the corridor; and (c) questions, attitudes, and perspectives, hopes, concerns related to AV technology and the shuttle pilot The interviews were recorded and transcribed to allow for structural

Table 3-2. Interviews

Methods	Sampling	Format / tools	Timeline
Key informant interviews	11	In-person or remote	April–May 2019
Rider/non-rider interviews	24 (2 per month)	In-person and/or remote interviews	June 2019–June 2020
Ongoing neighborhood stakeholder interviews	11 (1–2 per month)	In-person and/or remote interviews	June 2019–June 2020
Ongoing May Mobility fleet attendant and supervisor interviews	18 (1–2 per month)	In-person and/or remote interviews	June 2019–March 2020

analysis. A coding structure was developed to code all the interviews using the qualitative analysis platform, Dedoose[1], involving an iterative process of coding sections of interview narrative text with identified topics and themes. Researchers surfaced insights from interviews by mapping these topics and themes to identify patterns across the three previously defined audience groups: agnostic, aware, and rider.

3.3.4. Observations

Field observation took several forms, including direct participant observation of shuttle operation wherein researchers rode in the shuttles and engaged in the shared experience of riding while gathering data, as well as while waiting at shuttle stops and exploring the shuttle route. Researchers captured field notes from observations to record detailed accounts of what they experienced both qualitatively and quantitatively. While the number of in-field observation periods was limited by logistical constraints, the nature of the data collected helped fill important gaps and capture nuance not attainable via other forms of research or in the monthly reports from May Mobility.

Shuttle stop observations: Qualitative observations were conducted throughout the course of the pilot at all shuttle stops across days and times. Observations included capturing rider behaviors, questions asked, in-vehicle behaviors, and at-stop behaviors. The lines of inquiry investigated included: (a) community profile, (b) user behavior, and (c) pilot performance. In total, 349 observations were made between May 2019 and March 2020.

In-shuttle observations: In-shuttle observations were conducted to capture measurable, accurate, and invariable information throughout the course of the pilot, with a particular focus on the experiences of fleet attendants and riders. In some cases, field researchers attempted to capture specific quantitative observations within the shuttles to account for gaps in data sources available from May Mobility, such as the number of riders in the shuttles and time spent in AV mode. The lines of inquiry investigated included: (a) community profile; (b) user behavior; and (c) pilot performance. In total, 434 observations were made between May 2019 and March 2020.

3.3.5. May Mobility data

The research team aggregated various forms of data from May Mobility to assess how the pilot technology performed in comparison to pilot goals. This data was analyzed alongside public data and survey data to understand how discrepancies could be addressed and how the quality of service (perceived and actual) may affect attitudes towards AV technology.

Method and sampling

RESTful API service: A representational state transfer application programming interface (RESTful API) was provided by May Mobility in order to share programmatic access to May Mobility operational data with the research team (May Mobility, n.d.). The API was a returned data in a JavaScript Object Notation (JSON) format. Data resources available via the May Mobility API included: (a) geometry for the Little Roady route and for the Little Roady route segments (i.e., the path between each pair of respective Little Roady stop locations); (b) daily ridership activity and vehicle performance organized by vehicle shift (i.e., the continuous operation of a single vehicle, including start time and end time, start and end battery levels, and total ridership count); (c) vehicle shift segments (i.e., the driving of a vehicle from one stop to another, including stop times and counts of passengers entered, exited, or left at the curb) both updated at midnight the day after the day of operation in question; and (d) vehicle location, published in real-time.

Monthly reports: May Mobility released monthly reports to the research team which included qualitative reporting as well as quantitative metrics and figures, some of which corresponded to data from the API, but much of which appeared to be derived from separate internal systems. Request for more comprehensive reporting was made to May Mobility after initial reports were found inadequate to accurately report the performance of the shuttle. Subsequently, May Mobility reports were improved to include service insights (e.g., headways, SLA compliance interruptions and suspensions, incidents, construction impacts, driver training, fleet attendants' insights, and trends), ridership data (e.g., daily ridership

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[1] Dedoose is an application for analyzing qualitative and mixed methods research from sources including text, images, audio, videos, and spreadsheet data (www.dedoose.com).

totals, average ridership by day of the week), customer support intake, autonomy insights, and stop utilization insights, among others. When relevant, new topics such as wheelchair accessibility and winter preparation were added to the reports. May Mobility delivered 11 reports from May 2019 to March 2020.

3.3.6. Data warehouse and open data

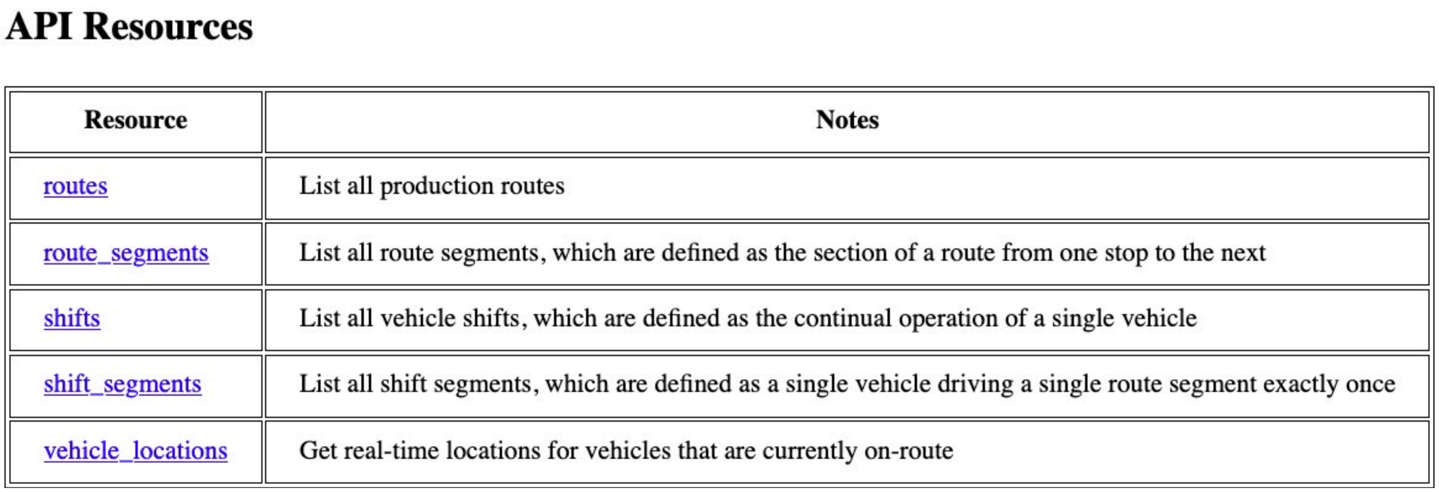
The research team also built a data warehouse, integrated within the platform operated by Stae, to support research throughout the life of the project. The data warehouse was constructed by first conducting an inventory of available data sources and then aggregating civic data relevant to the AV pilot and to the study area. The civic data warehouse also provided one location and secure management of all of the data that is captured throughout the research for ongoing reporting and analysis. The data warehouse supports public facing dashboards and visualizations and, more broadly, the publication of research data in an open data format for public consumption.

Public facing research data and dashboards can be found on the Little Roady Public Data Hub at *https://ridot.municipal.systems/*. ●

Table 3-3. Observation method and sampling

Methods	Locations	Quantity	Format / tools	Timeline
Shut stop observation	12 shuttle stops	349	Digital notes; photography	May 2019–March 2020
In-shuttle observation	In-vehicle	434	Digital notes; photography	May 2019–March 2020

Figure 3-10. API Resources from May Mobility (May Mobility, n.d.)



API Resources

Resource	Notes
routes	List all production routes
route_segments	List all route segments, which are defined as the section of a route from one stop to the next
shifts	List all vehicle shifts, which are defined as the continual operation of a single vehicle
shift_segments	List all shift segments, which are defined as a single vehicle driving a single route segment exactly once
vehicle_locations	Get real-time locations for vehicles that are currently on-route

Research Design

3.4. Limitations and Constraints

While the study yielded important findings related to the Little Roady Shuttle service, the following limitations should be taken into consideration while reading and citing the findings:

Data sharing and data collection challenges: The data available under the contract signed between RIDOT and May Mobility was limited. The research team requested access to additional data needed for analysis, but ultimately no changes were made to the API and changes to the monthly reports did not include sharing of additional machine-readable data. The level of data fidelity produced continued to limit the ability of the research team to fully interrogate initially posed research questions. For example, as a result of the lack of actual AV mode disengagement data from May Mobility, the research design relied on observations to ascertain how frequently disengagements occurred as well as the observable cause of disengagements.

Outreach challenges: Due to constraints around public-facing marketing efforts related to the project, there was a general lack of awareness of the project outside the service area. That, coupled with a lack of incentives for participation, led to lower survey responses than were initially targeted.

Cost of service and self-selection bias: Certain factors about the nature of the service and conditions within which the research was run makes it difficult to emulate real-world conditions. For example, the cost of the service was free to riders, which makes it difficult to discern what the true ridership would have been had it been offered at its true cost. Additionally, because there was no participant incentive associated with the rider/non-rider survey, respondents were largely riders of the Little Roady service, which may have skewed survey results surrounding attitudes and perceptions.

Cost transparency: With the exception of the contractual cost provided by RIDOT, no other data was made available by May Mobility on the actual cost of the Little Roady Shuttle service operations to May Mobility, which limits the research team's ability to determine financial sustainability and cost considerations.

External forces: COVID-19 led to disruption of the Little Roady Shuttle service, limiting ongoing data collection on the autonomous shuttle to March 2020. On March 12, 2020, May Mobility informed RIDOT that they were suspending Little Roady AV shuttle service operations, citing concerns with the COVID-19 pandemic. The service was suspended following the end of the service on March 13, 2020. Following a two-day service suspension, the missing shuttle service was replaced by a conventional RIPTA shuttle service until the end of June 2020. Limited data collection resumed associated with the RIPTA Shuttle service that replaced the autonomous shuttle service.

Limited electric vehicle-related analytics: Limited data was made available to the research team related to the operation of the shuttles as an electric vehicle (EV) (e.g., battery life, charging cycles, efficiency, etc.), significantly curtailing opportunities to analyze EV functionality in this context. ●

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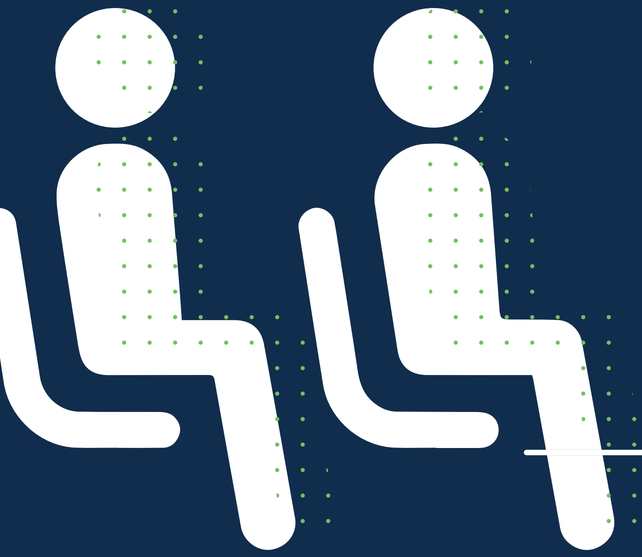
04

Findings

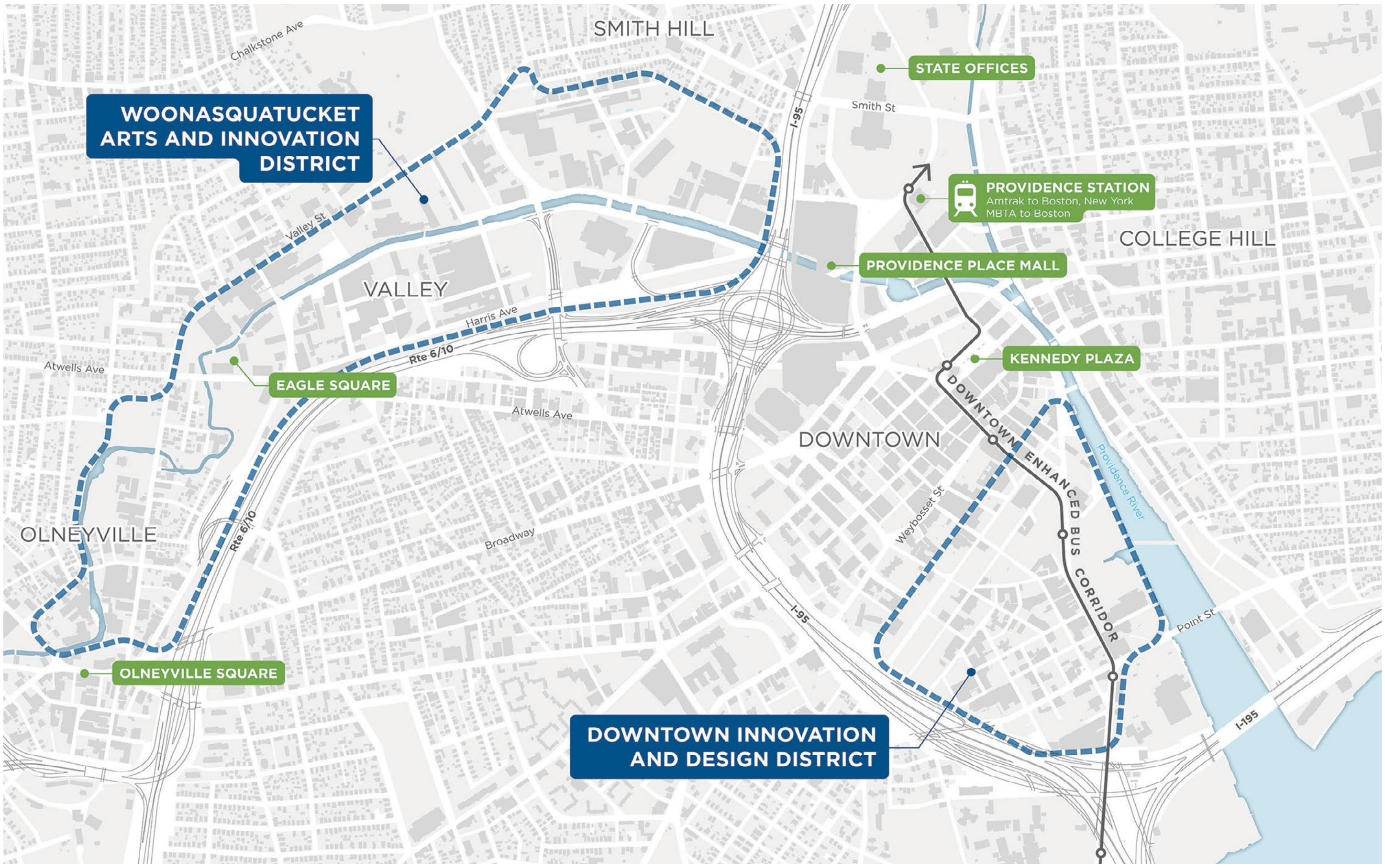
Core findings of this report are structured in alignment with the previously established lines of inquiry, and as such are divided across a neighborhood landscape assessment, attitudes and perceptions from the vantage points of multiple constituencies, user behavior and pilot performance, and user experiences with the pilot.



4.1. Neighborhood Landscape Assessment

This neighborhood landscape assessment is an analysis of the Woonasquatucket River Corridor, the area chosen for the Little Roady Shuttle service because of a gap in public transit services and a need for transit connectivity to downtown Providence (State of Rhode Island, n.d.). Consisting of more than 560 acres of land area, the Woonasquatucket River Corridor stretches from Olneyville to downtown Providence along the Woonasquatucket River and spans three Providence neighborhoods: Olneyville, Valley, and Smith Hill (City of Providence, 2018). The assessment in this section focuses on: (a) a brief overview of the developmental history of the neighborhood, (b) current development and transportation initiatives, and (c) current demographic structure of the neighborhood. Census tract 25 of Providence County that covers the majority of the Woonasquatucket River Corridor was used to develop the demographic profile of the neighborhood.

Figure 4-1. Woonasquatucket area (State of Rhode Island, n.d.)



4.1.1. History of the neighborhood

The Woonasquatucket River Corridor has a rich industrial history dating back to the 19th century. On the eastern edge of the shuttle service area, the neighborhood has historically met the State House area and downtown with a series of complex transportation infrastructure systems. Whether the Cove Basin from the mid-1800s or the elevated railroad tracks that traversed the area up until 1986, this portion of the Woonasquatucket River Corridor has always had a poor connection with the State House and downtown destinations, a situation not substantially improved upon with the development and opening of the Providence Place mall in 1999 (City of Providence, 2018).

In 2013, the RIDOT began construction on the replacement of 1,290 feet of the Interstate 95 Viaduct that was originally constructed in 1964. The replacement of this critical piece of regional transportation infrastructure is currently ongoing at a total cost of approximately $208 million. Even with this RIDOT project nearing completion, efforts are still needed to improve pedestrian and bicycle connections under the viaduct and through the mall to downtown Providence (City of Providence, 2018).

Along the south-eastern edge of the Woonasquatucket River Corridor, RIDOT announced in January 2018 the beginning of a $410 million reconstruction of the 6/10 Connector, a state highway that separates the Woonasquatucket River Corridor from the adjacent Federal Hill neighborhood. In addition to reconstructing nine bridge structures, five of which are structurally deficient, the project also includes: construction of a flyover ramp to allow Route 10 North traffic to access Route 6 West without traveling through Olneyville Square; a one-mile extension of the Washington Secondary Bike Path between Union Avenue and Tobey Street; two new pedestrian and bicycle bridges over the highway and railroad tracks at Dike Street and Tobey Street; a complete redesign of the Tobey Street bridge to allow two-way neighborhood-to-neighborhood vehicular travel; a complete redesign of Broadway and Westminster Streets as they cross over the highway to make them pedestrian-friendly gateways between Federal Hill and Olneyville; and the creation of more than four acres of former highway right-of-way for development (Rhode Island Department of Transportation, 2016).

4.1.2. Current development initiatives

Over a century of continuous heavy manufacturing use contaminated the soil and Woonasquatucket River with semivolatile organic compounds (SVOCs), free-phase hydraulic/lubricating oil, fuel oil, and dozens of other chemicals. The financial liability of contamination, which is expensive to remediate and return to other uses, became painfully clear by the 1970s when the Environmental Protection Agency (EPA) created the Superfund program to deal with severely polluted sites all over the country (U.S. Environmental Protection Agency, 2014). Vacant sites that are expected to have contamination but did not rise to the severe levels of Superfund sites—what we now refer to as brownfield properties—were hampered from redevelopment and locked in a state of underuse or abandonment.

The high cost of cleanup and redevelopment combined with an immense industrial downturn in the northeast after World War II created large concentrated swathes of brownfields in many cities, and Providence's Woonasquatucket River Corridor was not spared.

Encouraging brownfield clean-up, clearing the congestion on the Providence Viaduct, and improving safety were the primary motivators of RIDOT's Transforming the Providence I-95 Northbound Viaduct effort, implemented with the support of INFRA grant of $65 million. The project was central to the economic and environmental health of the Woonasquatucket River Corridor (Rhode Island Department of Transportation, 2019).

Accordingly, remediation and reuse of brownfields within the Woonasquatucket River Corridor is one of the top implementation goals of the City of Providence's Woonasquatucket Vision Plan 2018. This plan also identifies a number of related community goals and actions that will be prioritized and executed by the City and its partners (City of Providence, 2018):

Other key projects include:

- The City of Providence's Woonasquatucket River Greenway Extension Project, a $6 million project that enhances a one-

Figure 4-2. Woonasquatucket Vision Plan Project Area (modified from City of Providence, 2018)

The Woonasquatucket Vision Plan involved a unique process that ensured strong participation from a diverse range of residents, artists, makers, business owners, developers, and city leaders to ensure the priorities, strategies, and actions included in this Plan are in line with the interests of the community.

mile section of the greenway between downtown and Eagle Street through a separated off-road bicycle and pedestrian path, a series of parks, and green infrastructure along the Woonasquatucket River. Construction on the project was expected to be completed in 2022.

- Farm Fresh Rhode Island's new campus, which includes a 79,000 square foot building to provide centralized food processing space and distribution services to local farmers and prepared food vendors, as well as serve as a large farmers market on weekends.
- The Gotham Greens hydroponic greenhouse, a 94,000-square foot building that brings year-round urban agriculture at a large scale to the Corridor.

City of Providence Department of Planning and Development representatives also indicated an additional major project includes the redevelopment of the former Umicore building on Sims Avenue, which is now owned by the Providence Redevelopment Agency.

4.1.3. Demographic structure

The sampling plan discussion in the previous chapter was focused on the comparison of city-level data with the demographics and transit behavior of the respondents in order to assess fair representation and distribution. In this section, the focus is on the demographics of the service area of Little Roady shuttle. In order to get an accurate snapshot of the community profile, the research team sourced the U.S. Census Bureau data available on the census tract 25 of Providence County that covers the majority of the corridor area.

The Woonasquatucket River Corridor consists of vibrant neighborhoods with diverse cultural groups. The demographic profile of occupied housing units of the area is 53.4% White alone, 23.6% Hispanic or Latino, 7.3% Asian, 11.8% Black or African American, 6.1% some other race, 5.1% two or more races, and 0.9% American Indian and Alaska Native (U.S. Census Bureau, n.d.-a). The area has a majority middle age population with 37.8% under 35 years, 21.5% between 35 and 44 years, 15.7% between 45 and 54 years, 17.1% between 55 and 64 years, 4.6% between 65 and 74 years, 0.9% between 75 and 84 years, and 2.4% over the age of 85 (U.S. Census Bureau, n.d.-a).

Most of the residents have college education. Approximately 8% did not graduate from high school, 20.2% are high school graduates, 14.5% have some college or an associates degree, and 57.8% have bachelor's degree or higher (U.S. Census Bureau, n.d.-a). Thirty eight percent of the population falls below the poverty line, and the median income is $62,248. Looking at the income groups of the population, 21.3% earned less than $35,000, 12.6% between $35,000 and $49,999, 25.3% between $50,000 and 74,999, 10.7% between $75,000 and $99,999, 17% between $100,000 and $149,999, and 13.1% over $150,000 (U.S. Census Bureau, n.d.).

Ten percent of the workers 16 years or older in census tract 25 households reported not owning a vehicle (*N* = 1,707). Of the workers with no vehicles, 39.1% reported driving a car, truck, or van alone to work, 12.4% reported using a carpooled car, truck, or van, 8.3% used public transportation (excluding taxi cab), 23.7% walked, and 16.6% used taxicab, motorcycle, bike, or other mode as a means of transportation to work. Of the 1,707 workers who responded to the ACS survey, 65.4% used a car; 10.8% carpooled; 4.0% used public transportation; 9.0% walked; 3.0% used taxicab, motorcycle, bike, or other mode; and 7.9% worked from home (U.S. Census Bureau, n.d.-b).

A part of the reason for the low use of public transit service is that the area is a transportation desert with no public transit service available between Chalkstone Avenue and Atwells Avenue, leaving a 0.5 to 0.75-mile swath of the Woonasquatucket River Corridor without access to any form of public transit. With RIPTA's Route 26 discontinued and the inability for riders to easily walk from areas south of the river to bus stops located north of the river on Promenade Street and Kinsley Avenue, the only option is either to own and ride a vehicle or, for those who do not, walk or take a taxicab, motorcycle, or bicycle. The City's Vision Plan 2018 identified an action plan to work with RIDOT to explore and test new public transportation options including an autonomous shuttle between Olneyville Square and Providence Station via the Woonasquatucket River Corridor (City of Providence, 2018). The TRIP mobility challenge identified the Woonasquatucket River Corridor instead of Downtown and West End because the Corridor faced the mobility and equity challenges outlined here.

The impetus to close the transportation gap in the Corridor was widely acknowledged and appreciated by Little Roady passengers. Many participants also acknowledged the transportation gap filled in a low-income neighborhood that many felt had not previously received sufficient investment from the City. For example, one of the participants stated

> *"I think it is really cool that this wasn't something just given to the wealthier neighborhoods, uh, over by Brown and putting this in this part of town shows an investment in Olneyville that that community hasn't always received in the past. So, I'm glad it's not just something that goes up and down Thayer street and Hope street for example. So, I think it is great."*

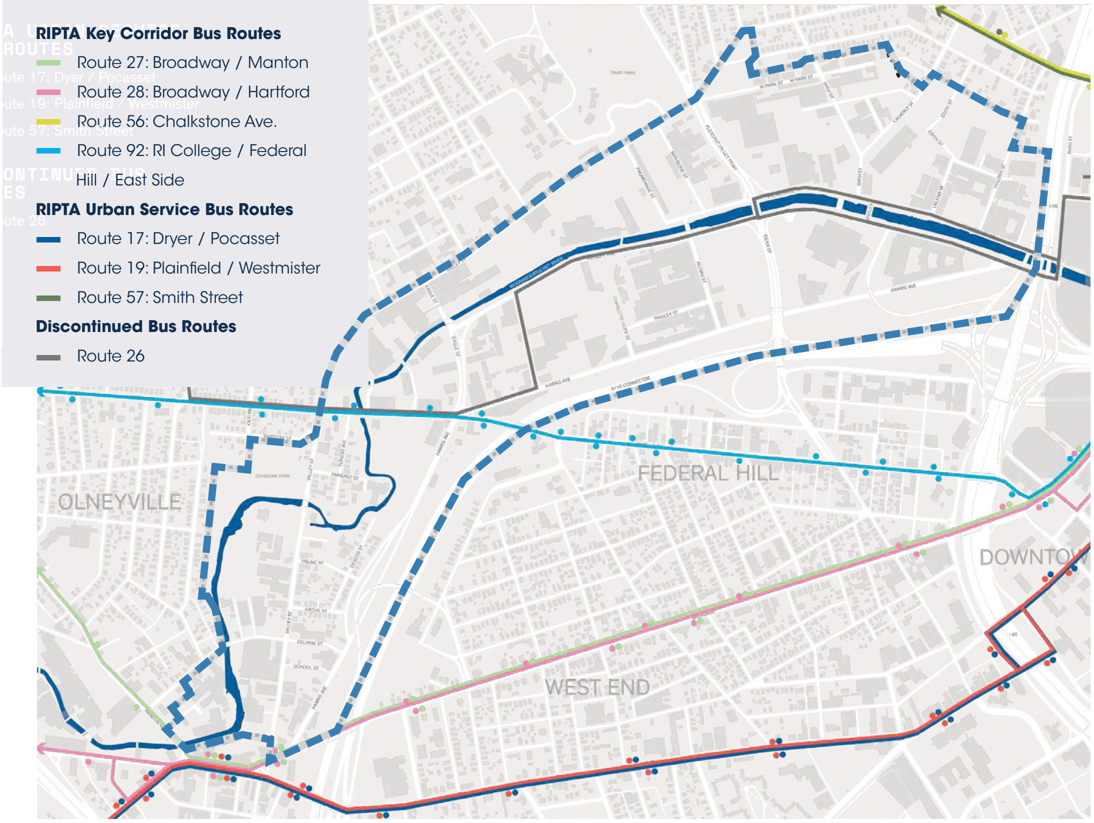
Another participant remarked

> *"The area is changing a lot. It is the historic manufacturing heart of Providence, of New England, of the United States, frankly, because the earliest manufacturing that started up in this country was along this river here ... So, it's an area that's full of converted and converting mills. So, it's a really, dynamic and changing area... So, it's great to kind of connect that neighborhood to downtown."*

The neighborhood assessment demonstrates that the Woonasquatucket River Corridor was an appropriate use case for the autonomous vehicle shuttle pilot project.

Figure 4-3. Woonasquatucket area demographics (modified from City of Providence, 2018)

Figure 4-4. RIPTA Service in Woonasquatucket area (modified from City of Providence, 2018)




ISLAND AND PROVIDENCE PLANTATIONS
HOPE
LITTLE ROADY
AUTONOMOUS SHUTTLE PILOT PROJECT
RI DOT
MAY
THANKS TO OUR PARTNERS
P
QUONSET
RIPTA

4.2. Attitudes and Perceptions

4.2.1. Overall sentiment

When asked to indicate overall interest in using various forms of AV technologies (i.e., AV ride-sharing, riding in an AV shuttle, and riding in a personally owned AV), participants responded generally positively (Figure 4-5). Of all responses to the seven-point scale of interest across the three types of AV categories, 20% of responses were between one and three (*not interested* to *slightly interested*), while 67% were between five and seven (*slightly interested* to *very interested*). As such, overall participant interest was high with regard to engaging with all three forms of AVs, but expressed interest was lowest among the three categories with regard to individually-owned AVs, which is an indication that participants may be generally more interested in AVs as a form of public transit as opposed to private vehicles.

Upon condensing all responses to the item related to interest in AVs across the three user categories, overall average level of interest in riding in an AV shuttle was highest among *riders* (*M* = 6.1), followed by *aware* (*M* = 5.3), and *agnostic* (*M* = 4.8), where one is *not interested at all* and seven is *extremely interested* (Figure 4-6). While causality for these differences cannot be determined, the results nonetheless indicate that increased familiarity with the Little Roady shuttle was associated with higher levels of interest in riding AVs. This finding indicates it may be possible that as the public increasingly interacts with AV technologies, attitudes toward the technology may become increasingly positive.

Support for the continuation of the Little Roady shuttle pilot was very high, as 94.8% of all survey participants responded *yes* to a question about extending the pilot (*Would you support an extension of the pilot program for another year or more?*). Additionally, when asked how much they would be willing to pay for an AV shuttle service (along with an indication of the current one-way RIPTA bus fare rate of $2), the median response from all participants was $2. This finding is particularly notable because the Little Roady shuttle was available to riders at no cost for the duration of the pilot. In rider interviews, however, one emergent theme was that the shuttle would be of most value if there were a unified payment system that connected many forms of transportation together, as well as the option for a monthly service plan as opposed to a single-ride ticketing system.

When asked more broadly about the feasibility of AV as a conventional transit option, 48% of survey participants indicated they believe AV could become a conventional transit option within the next five years, while 29% indicated it would take between five and 10 years, and 14% estimated it would take more than 10 years (Figure 4-7). A common sentiment among interview participants was that the pathway to AV becoming commonplace required overcoming hurdles related to regulation and technology, but that public opinion and general comfort with the technology would be a significant challenge.

Figure 4-5: Interest in riding in autonomous vehicles (by AV type) (*link*)

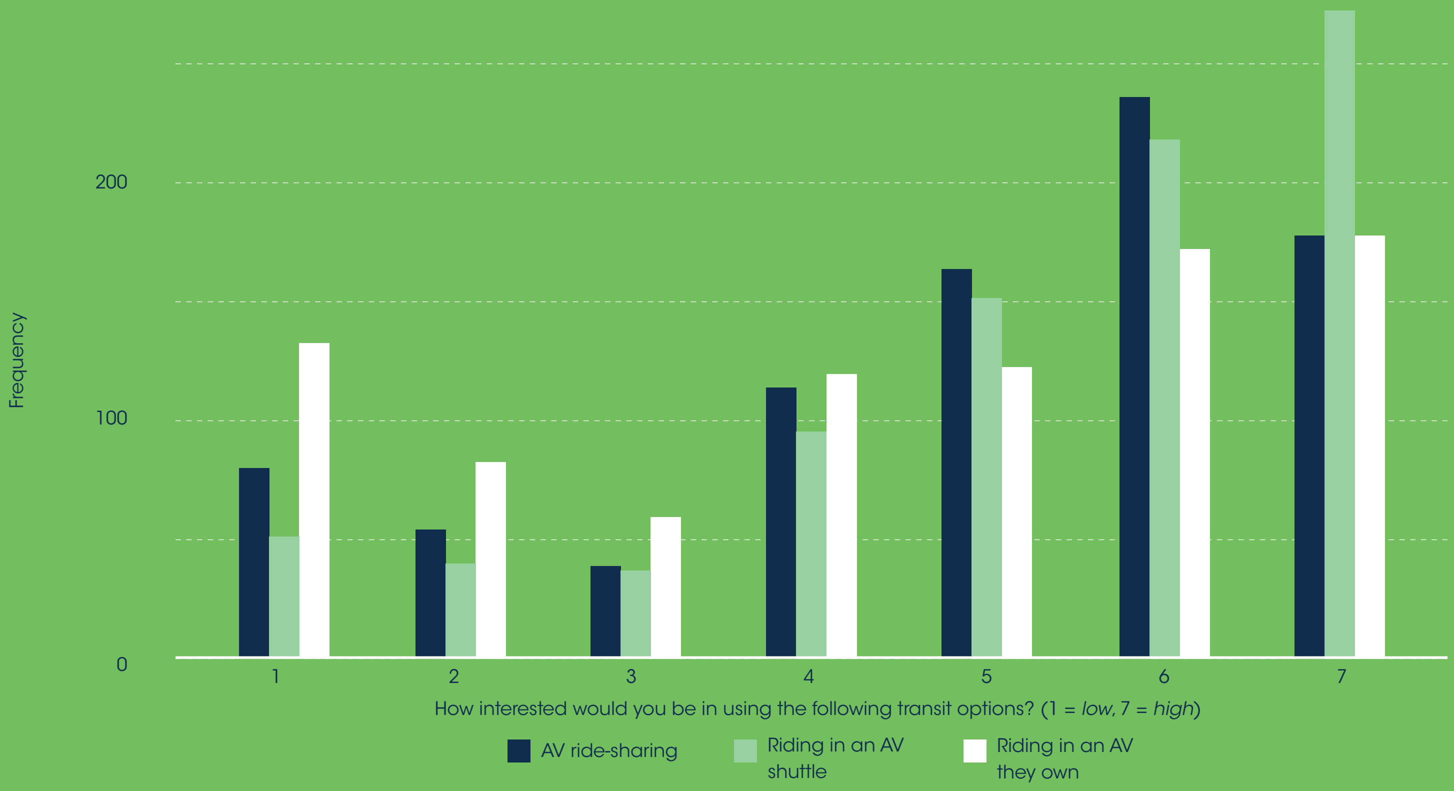
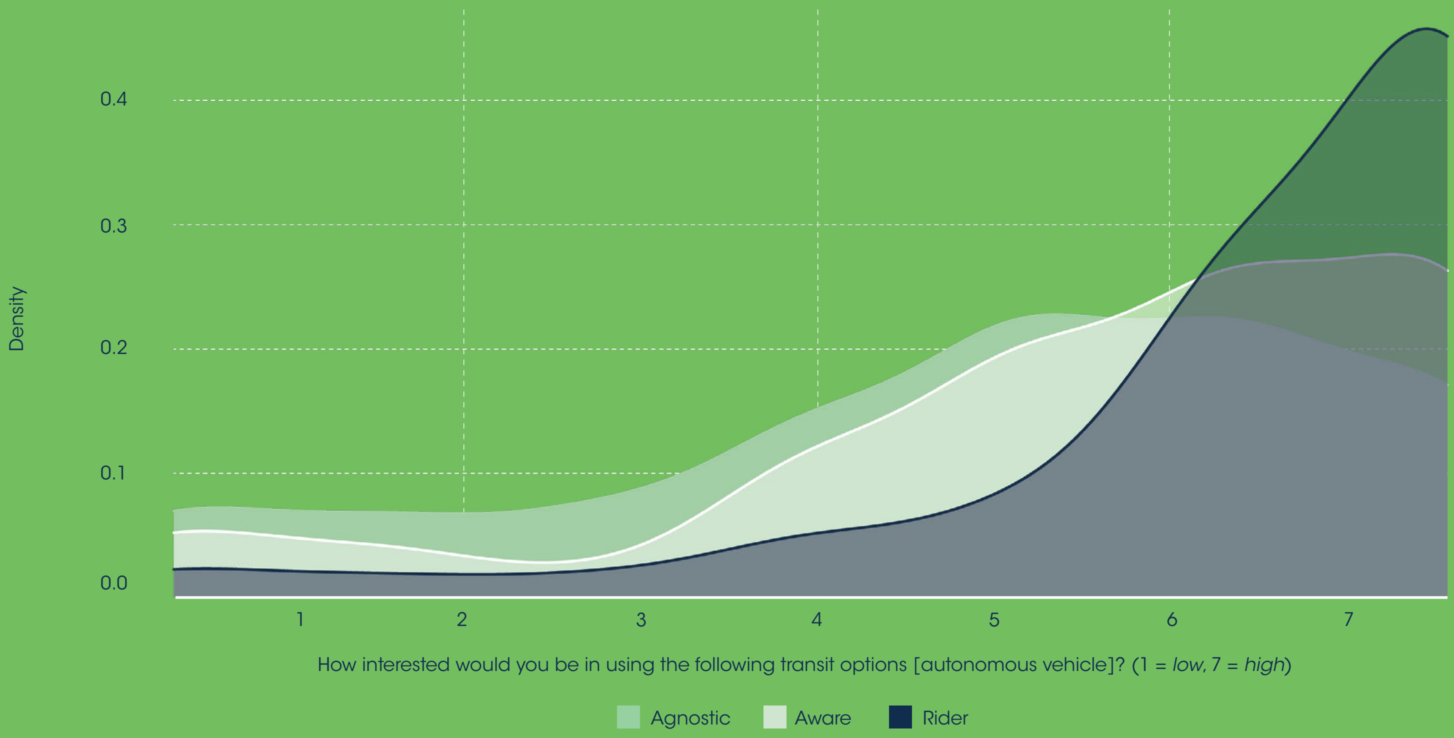


Figure 4-6. Interest in riding in autonomous vehicles (by user type)



> *“Public opinion, some regulations that can be cleared out of the way. Technology itself has a way to go. A lot of people working on it. Technically, it’ll work pretty well in the next three to five years, but public opinion will take longer. Ten years.”*

Figure 4-7. Perception of AV as a conventional transit option (*link*)

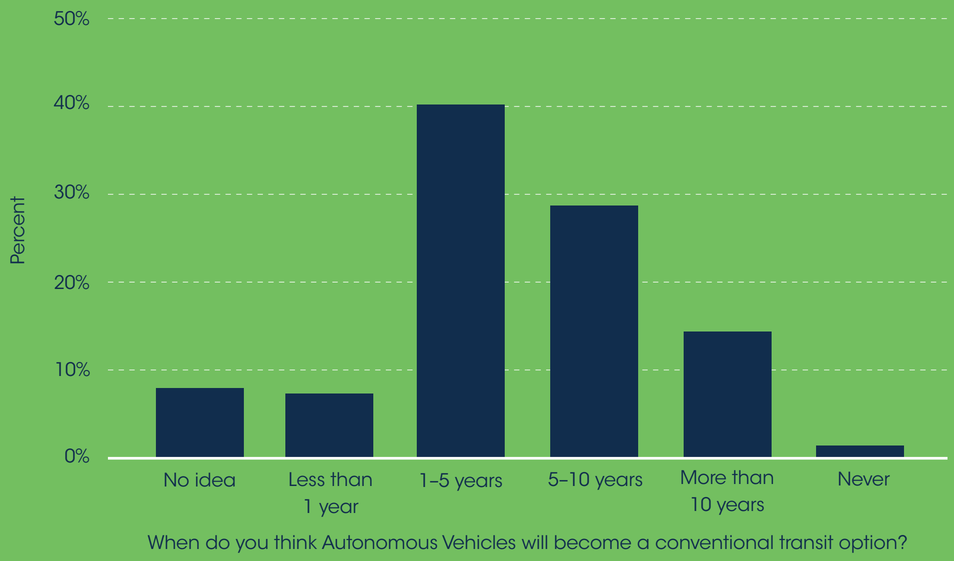
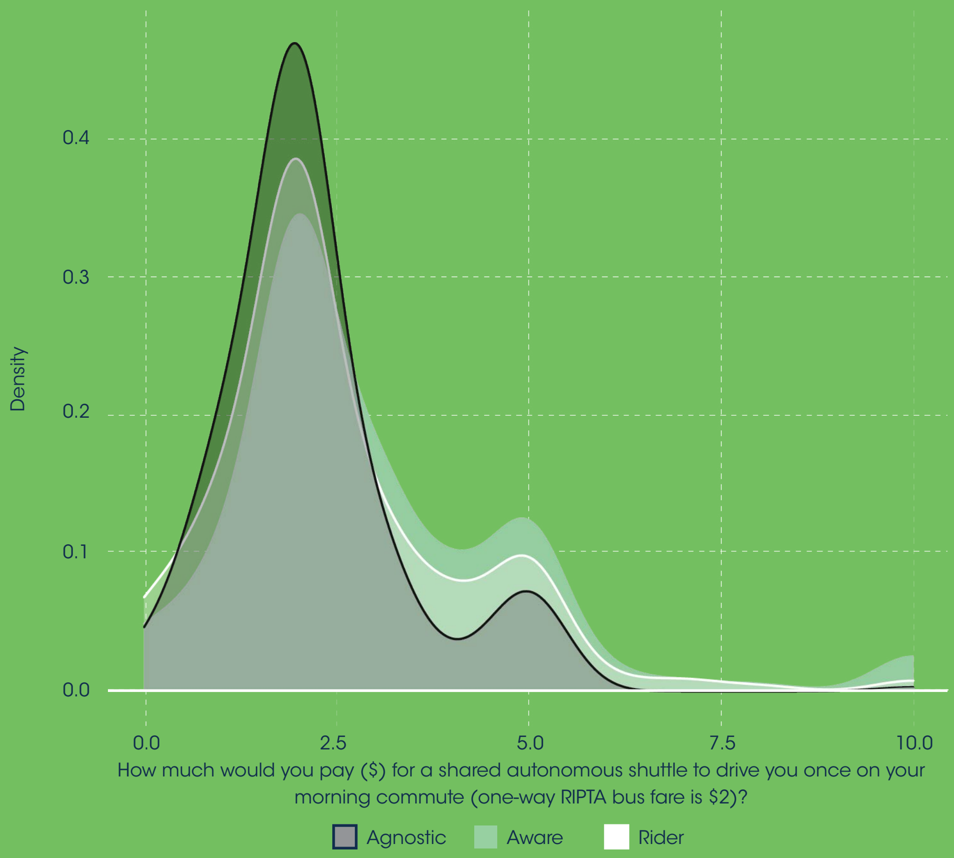


Figure 4-8. Reported willingness to pay for AV shuttle rides

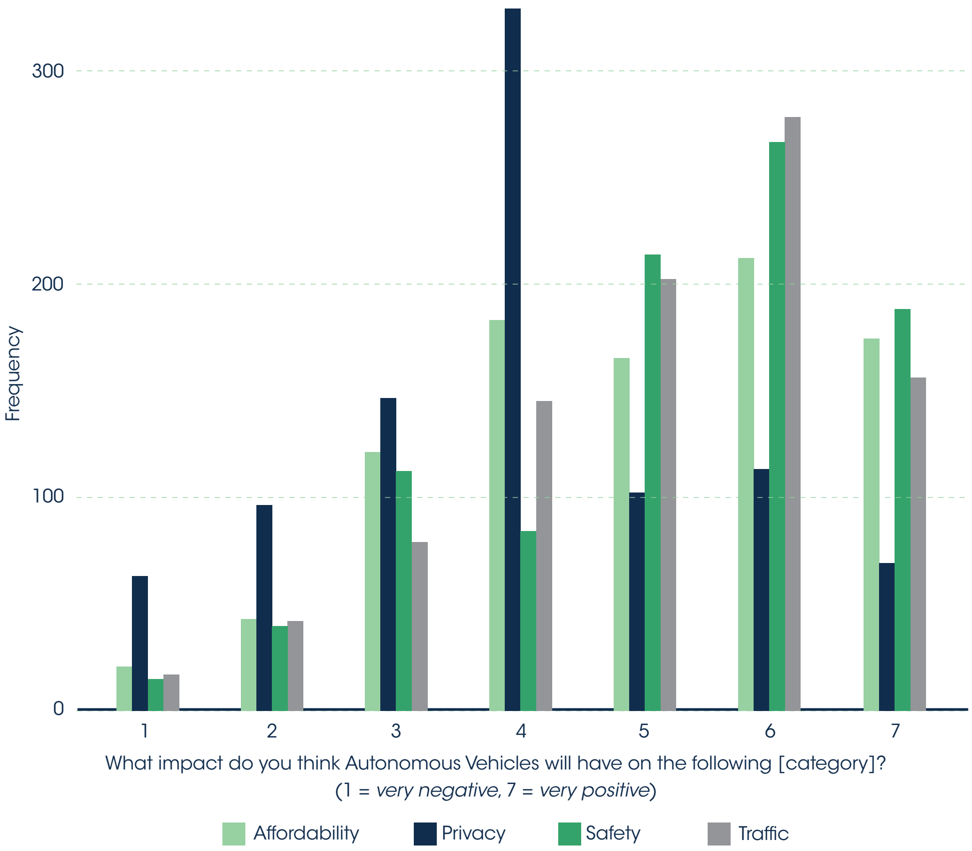


4.2.2. Perceived future impacts of AV

To gain a general sense of participants' perceptions of the future impacts of AV technologies, participants were asked to indicate on a scale from one (*very negative*) to seven (*very positive*) about the impact AV will have in the future on affordability, privacy, safety, and traffic. Perceived impact was generally positive for *traffic* (*M* = 5.1), *safety* (*M* = 5.2), and *affordability* (*M* = 4.9), with the lowest responses related to *privacy* (*M* = 4).

However, a wide range of concerns about the future of AV emerged in interviews, with topics including concerns workforce job loss (i.e., driver job displacement), ethical concerns related to algorithms that underpin AV safety decisions, and cost (i.e., potential expensive infrastructural changes to make widespread AV implementation feasible). In contrast with the survey responses, concerns related to privacy did not emerge as strong themes in participant interviews.

Figure 4-9. Perceived future impacts of AVs (by category) (*Link*)



> *"My main concern with any autonomous vehicle—not just a Little Roady one—is how it decides, like if it has to make a decision between hitting the lady with the stroller or running over the other person riding their bike, like or hitting an oncoming car, like there's gonna be situations in which the car needs to choose between people. And we're putting a car in a position to make that choice. A computer in a position to make that choice. The choice is completely based on an algorithm that we install in it. So, who is to blame when it makes that choice? It's not the car, is it the person who designed the car? Is it the person that serviced it? Like, I don't know."*

4.2.3. Perceptions of safety

Using *driving yourself* as a baseline, survey participants were asked to indicate how safe they feel using various transit options (i.e., autonomous vehicles, bike or scooter, bus, and ride-share) on a seven-point scale from one (*much less safe*) to seven (*much safer*). Autonomous vehicles, buses, and ride-shares were all perceived as generally equivalent to *driving yourself* in terms of safety (*M* = 4.1, 4.2, and 3.8, respectively, with 4 representing *neutral*), while bike or scooter was perceived as less safe (*M* = 3.1) (Figure 4-10). These results are interesting, as ethical concerns as related to safety-related decisions emerged in participant interviews.

Looking across user categories at the difference between perceptions of safety related to autonomous vehicles and driving, participants who had ridden in the Little Roady shuttle reported higher overall perceptions of safety (*M* = 4.8) than the aware (*M* = 4.0) and agnostic (*M* = 3.8) participants (Figure 4-11). Similar to results related to AV sentiment overall, causality cannot be determined, but there nonetheless is a positive relationship between perceptions of safety of AVs as a mode of transit and direct experience with the Little Roady pilot.

Figure 4-10. Perceptions of safety: Driving vs. other modes of transport (*link*)

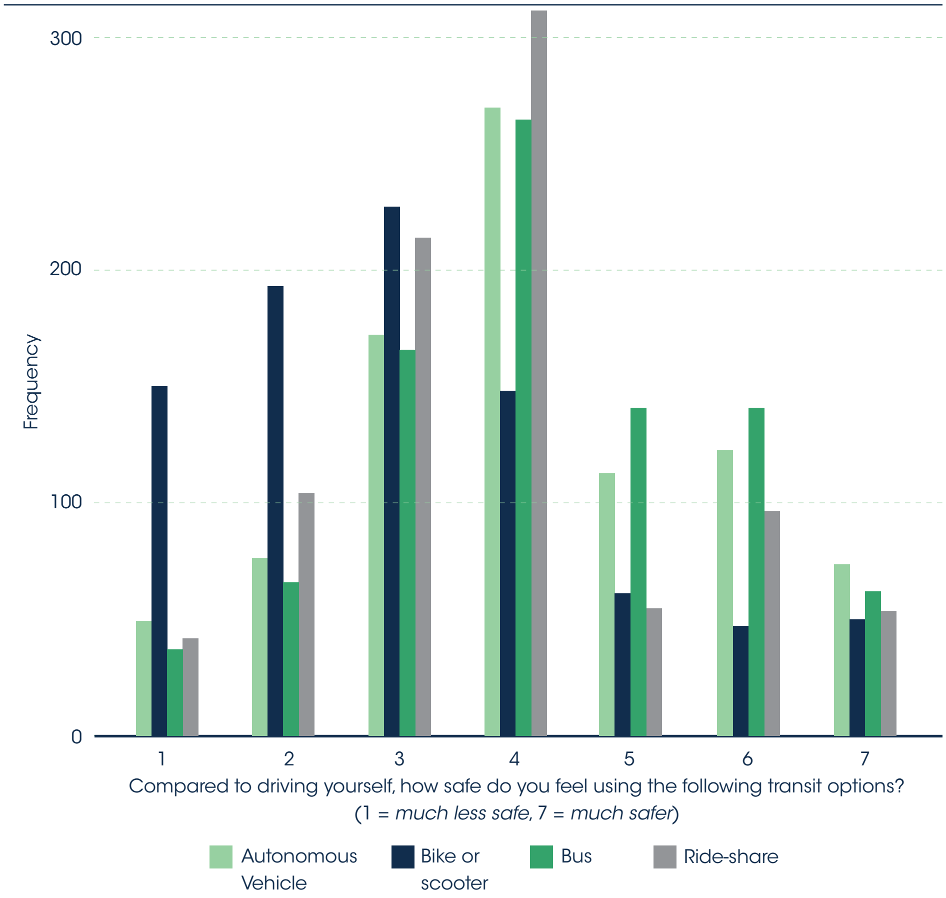
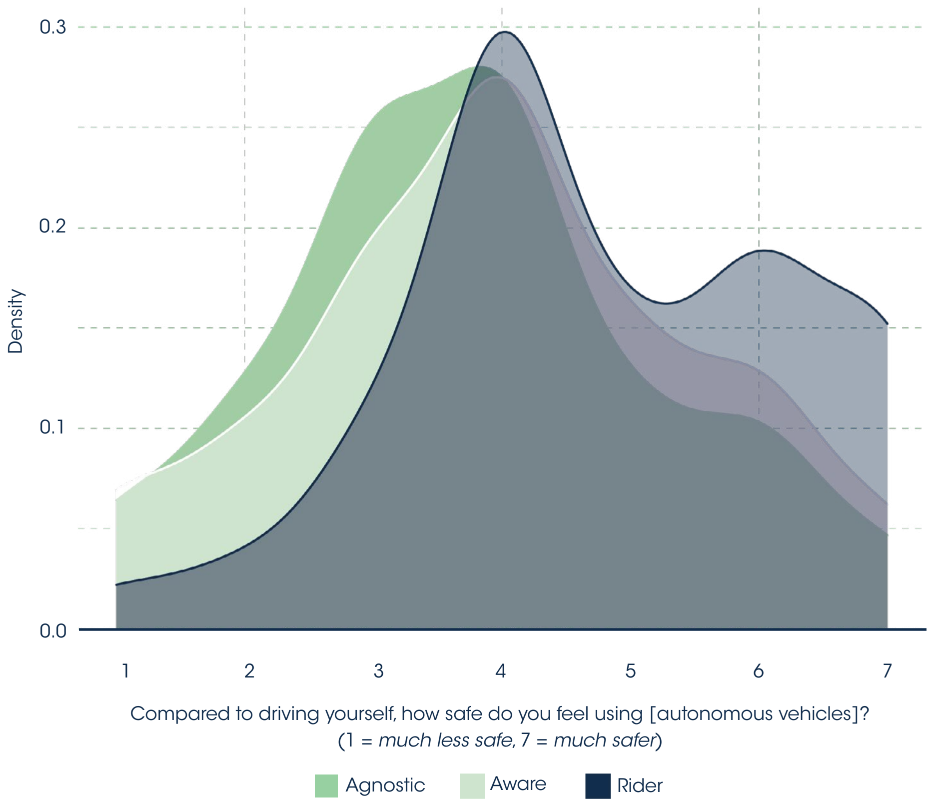


Figure 4-11. Perceptions of safety: Driving vs. AVs (by user type)



4.2.4. Perceptions of the role of government in regulating AV

Survey participants were asked to indicate the degree to which government investment and regulation should be prioritized in relation to autonomous vehicles as related to specific factors (i.e., environment, infrastructure, insurance, public transit, and safety), using a seven-point scale of priority from one (*lowest priority*) to seven (*highest priority*). Participants indicated safety was the highest priority: 55% of respondents said that safety was their top regulatory priority, and 85% had safety as a top-two regulatory priority. (Figure 4-12).

"Safety, first and foremost. We've seen this over and over again. We've seen companies trade off profit over safety which is not what the general public wants. Then there's the ethical dilemma about running over the lady or the little kids. It's dark, but someone has to make those decisions. Maybe it's the government's role to facilitate these conversations with the ethicists and such."

One participant perceived predictability as a key determinant for the success of AV vehicles and indicated that the government could play a role in making roadways conducive to predictability. Other infrastructural changes and maintenance suggestions included improved communication of traffic signals with AV vehicles and maintenance of signs and pavement distinguishing areas for use by AVs.

"I think that we need to shore up our roads and our infrastructure to make it safe for people as possible even without those autonomous vehicles, before we put more of them on the road because I think also like, you know, with any driving scenario, as with an autonomous vehicle, predictability is key. If we can make our roadways conducive to predictability, then the computer will have an easier time."

With regard to the impact of automated vehicles on the transformation of the workforce, many interview participants framed autonomous vehicles as one component of a broad shift toward automation.

"I think the government's role is to set up public transportation infrastructure. And if that's with people-driven vehicles, that's with people-driven vehicles. If it's with autonomous vehicles, then it's with autonomous vehicles."

"Any time you automate a process, jobs will get lost, right? So, this is just a little—if it's five people around, it's not a big deal, and it doesn't have an attendant—but in the long run, these are real jobs. And the unions are going to be watching out for that because we have very strong unions in Rhode Island, which is completely—it's not resistance of the passengers—but that's resistance maybe of the people that are employed there and their families and their livelihoods being threatened."

4.2.5. National survey, Rhode Island experimental survey, and driver experiment

In October 2019, the research team members at the Taubman Center for American Politics and Policy at Brown University, in partnership with research and analytics group YouGov, conducted two surveys to understand public perceptions of autonomous vehicles.[1] One survey instrument reached a nationally representative sample of American adults ($N = 1{,}000$), and a second survey instrument reached a sample of Rhode Island residents ($N = 500$) representative of the state. The national survey sample was weighted based on gender, age, race, and education. Both surveys included a variety of modules exploring social, economic, and political questions, as well as a series of questions regarding participants' perspectives on autonomous vehicles

Similar to the Little Roady-specific survey above, survey questions sought to measure participants': (a) familiarity with AV technology, (b) interest in riding in autonomous vehicles, (c) perceived impact of AV technology on multiple factors (i.e., safety for vehicle passengers, safety for cyclists and pedestrians, traffic, cost of transit, and privacy), and (d) perceived regulatory priorities (i.e., safety requirements, environmental standards, investing in infrastructure for AV technology, investing in AVs for public transit, access for under-served communities, and retraining transit workers).

Additionally, the research team partnered with RIPTA to explore perceptions related to AV technologies among professional transit drivers ($N = 24$) and whether such perceptions change following hands-on experiences with AV shuttles. This section includes a summary of findings from the national survey, Rhode Island experimental survey, and the driver experiment.

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[1] For additional information related to the findings included in this section, see: Armstrong, B. (2020). Will you let a robot give you a ride? Understanding popular perceptions of autonomous vehicles – Draft working paper (*link*)

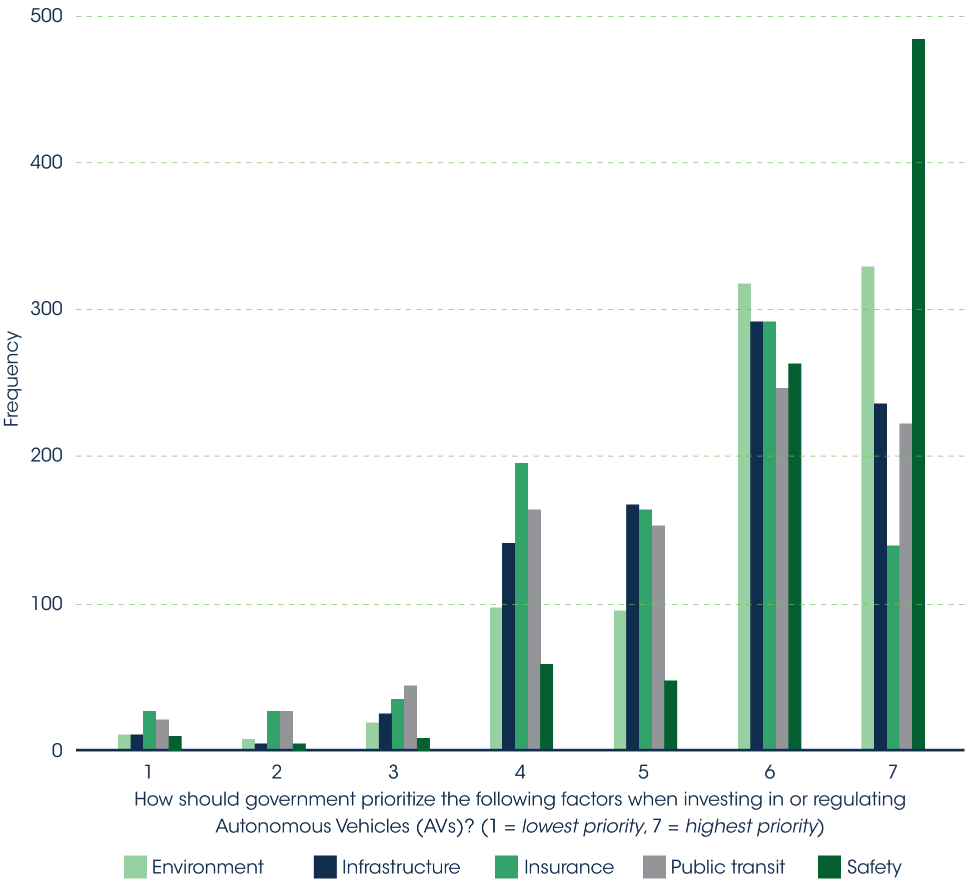
National survey

The principal purpose of the national survey was to understand why some people perceive autonomous vehicles more favorably than others.[2] Since AV technology is still in development and its potential social and economic effects are uncertain, we did not field the survey to test a clear set of hypotheses. We did, however, seek to understand the relationships between knowledge of, and attitudes (e.g., interest, impact, and regulation) toward AV technologies. The results presented below are primarily descriptive, reporting the responses to the major question and exploring the predictors of interest in AVs.

There are several patterns in the national survey results that are unsurprising. For example, younger individuals who are more familiar with AVs also express more interest in riding in them. However, while increased familiarity with AVs is associated with an interest in riding AVs, it is not associated with differences in projections of AVs' impact on safety or traffic. In other words, participants familiar with AVs are not more likely to report that AVs will be better for road safety or traffic than those who are unfamiliar, other factors constant.

These findings raise questions about how the information that individuals have about AVs might shape their attitudes toward their prospective impact.

Figure 4-12. Prioritization of AV regulations factors (by issue area) (*link*)



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[2] For more detail on the study objectives, see: Armstrong, B., & Yokum, D. (2019). Regulating innovation: Lessons from an autonomous vehicle pilot project: Pre-analysis plan—Draft. (*link*)

Key findings from the national survey

1.

A far higher share of participants indicate they are *uninterested* (50%) compared to *interested* (28%) in riding in an autonomous vehicle (Figure 4-13).

2.

There are strong demographic predictors of interest in AVs: individuals who are younger, have more education, and are male are more likely to be interested in riding in AVs (Figure 4-15). The difference by education is particularly stark (Figure 4-14).

3.

Among the strongest predictors of interest in AVs is familiarity with AV technology (Figure 4-15). In other words, the more familiar a person reports being with AVs, the more likely they are to report that they are interested in riding in an autonomous vehicle.

Figure 4-13. Interest in AVs, national sample

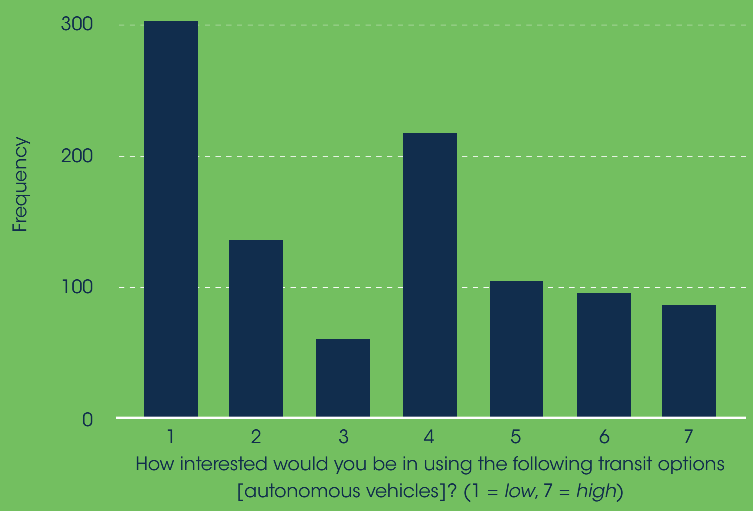


Figure 4-14. Interest in AVs (by education)

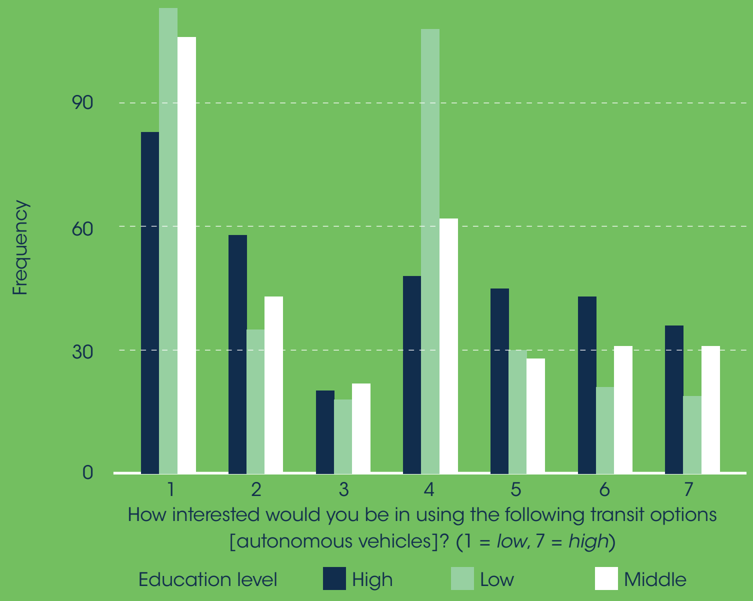
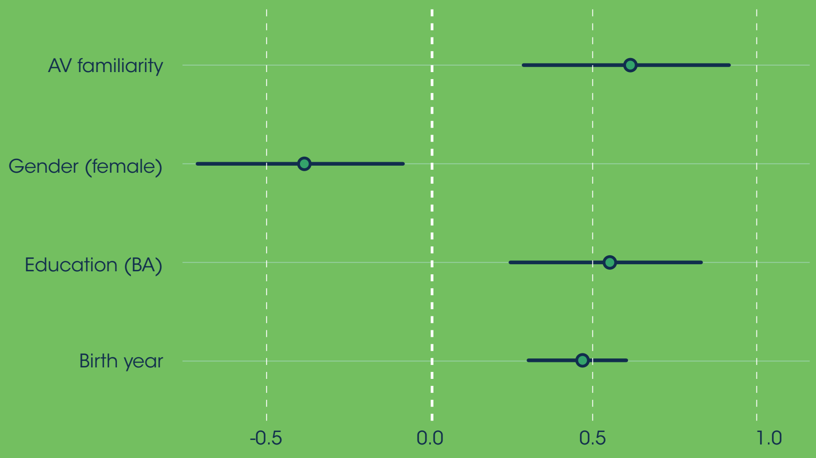


Figure 4-15. Interest in AVs (by education)*



4.

Whereas participants projected that AVs will have a somewhat negative impact on safety, they project a mostly neutral effect on traffic and the cost of transit (Figure 4-16).

5.

Greater expressed interest in AVs is associated with higher perceived positive impacts of AVs. However, the degree of self-reported familiarity with AVs was not associated with perceptions related to future impacts of AVs on safety or traffic (Figure 4-17).

6.

A majority of participants (76%) reported that their top regulatory priorities for AVs relate to safety requirements. However, participants who were more familiar with AVs or projected AVs' impact on safety to be higher were more likely to list a non-safety issue as their top regulatory priority, controlling for other covariates (Figure 4-18).

Figure 4-16. Impact of AVs, national sample

Figure 4-17. Predictors of AV impact

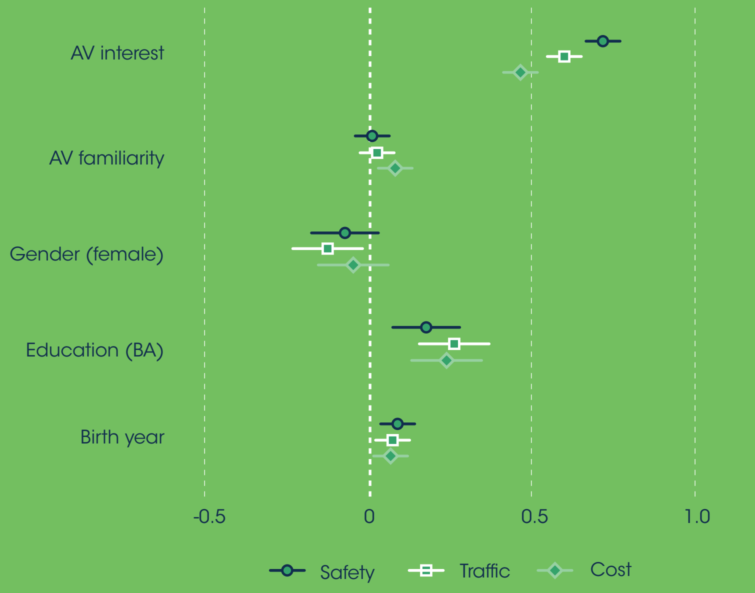
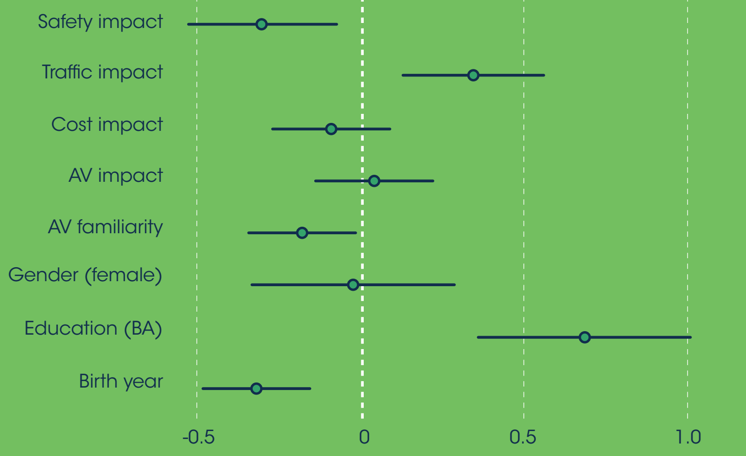


Figure 4-18. Predictors of the regulation of AVs



Rhode Island experimental survey

In contrast with the national survey, the regional Rhode Island experimental survey was designed to explore whether new information could influence perceptions of autonomous vehicles. Participants were randomly assigned to one of three treatment conditions (*pro-AV*, *con-AV*, and *control*). All participants were presented with a body of text about autonomous vehicles, with the framing of the text determined by each participant's respective treatment condition.

The pro-AV treatment condition included a series of quotations from news articles and individuals describing the positive possibilities and progress of AV technology, while the con-AV treatment condition included text of a similar length emphasizing the limitations of AV technology and difficulties these vehicles have faced in testing thus far. The control condition included information from encyclopedic sources about the sensing system that is core to most AV technology (Appendix A).

Before participants received the treatment text, they were first asked about their familiarity with AVs. Then, after receiving the treatment, participants reported: (a) their interest in riding in an AV, (b) their perceptions of projected impacts of AVs on a variety of factors, and (c) their regulatory priorities in relation to AVs. The treatment effects reported below compare the responses of participants across conditions.

The findings report unconditional treatment effects, as well as treatment effects conditioned on an individual's self-reported familiarity with AVs. The models that include the treatment as well as an interaction term (the treatment interacted with AV familiarity) aim to understand if the treatment had a different effect on participants with high familiarity than it did on those with low familiarity.

This interaction term can help pinpoint what about the treatment might be having an effect. If the treatment has more impact among low-familiarity individuals, then any treatment effect could be the result of the information providing an initial frame for individuals to view the technology. If the treatment has a similar effect for low- and high-familiarity individuals, then it would be more reasonable to assess that any treatment effect is due to the information being a new perspective on autonomous vehicles. Of course, the data available cannot rule out the possibility that low-familiarity individuals and high-familiarity individuals both react in the same way to the treatment, but for different reasons. Key findings from the Rhode Island experimental survey:

1. The pro-AV treatment did not have a significant effect on participants' level of interest in riding AVs, how they perceived the impact of AVs on safety, or how they prioritized safety regulations as a regulatory priority.

The pro-AV treatment did have a positive effect on participants' prioritization of government investments in AV technology (e.g., AV infrastructure, AVs for public transit).

2. The Pro-AV treatment also had a positive treatment effect on how participants prioritized government investments in AV technology, conditional on individuals' familiarity with AVs. Within treatment groups, individuals with more pre-existing AV familiarity were less likely to prioritize investment in AV technology. However, the coefficient on the interaction term between the pro-AV treatment and AV familiarity is positive and statistically significant. In other words, the pro-AV treatment had a larger effect on participants who self-reported greater familiarity with AVs as related to how they prioritized investment in AV technology.

3. The con-AV treatment had a negative and statistically significant treatment effect on individuals' interest in riding AVs, as well as their perception of AVs' impact on safety. Participants presented with Con-AV framing about AVs were less likely to express interest in riding them and reported believing that AVs would have a more negative impact on road safety. This treatment effect holds across reported familiarity with AVs, although the treatment does not seem to vary in degree by individuals' familiarity with AVs.

**Note: Figures describing treatment effects illustrate the direction of the effect of treatment (positive or negative) and its statistical significance. If the point estimate for a model is positive (right of the dashed line) and the error bars do not cross the dashed line, then the treatment effect for that model is positive and statistically significant ($p < 0.05$). The size of the point estimate is scaled such that an estimate value of 1.0 is equal to one standard deviation above the mean for that variable. For example, on average, negative information about AVs (the con-AV treatment) translated into an approximately 0.5 standard deviation decline in an individual's interest in AVs.*

Figure 4-19. Pro-AV treatment effects

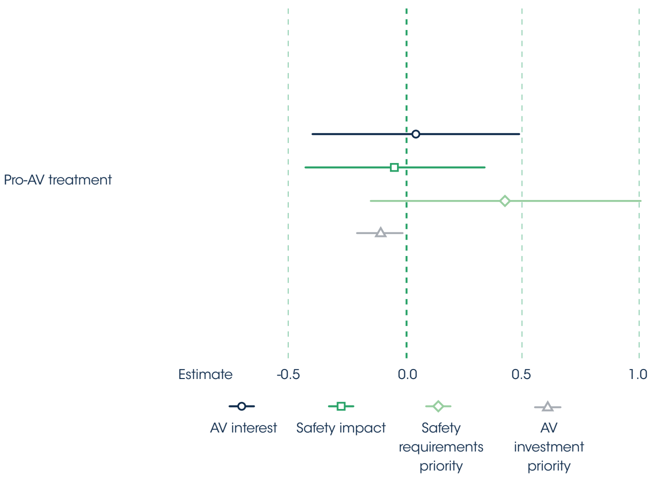


Figure 4-20. Pro-AV treatment effects conditioning on AV familiarity

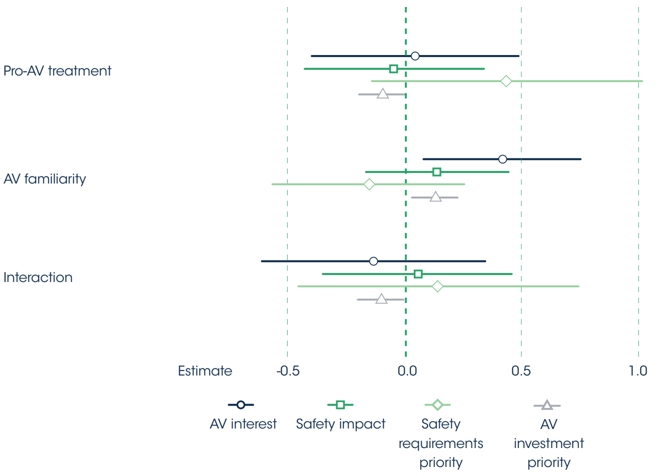


Figure 4-21. Con-AV treatment effects

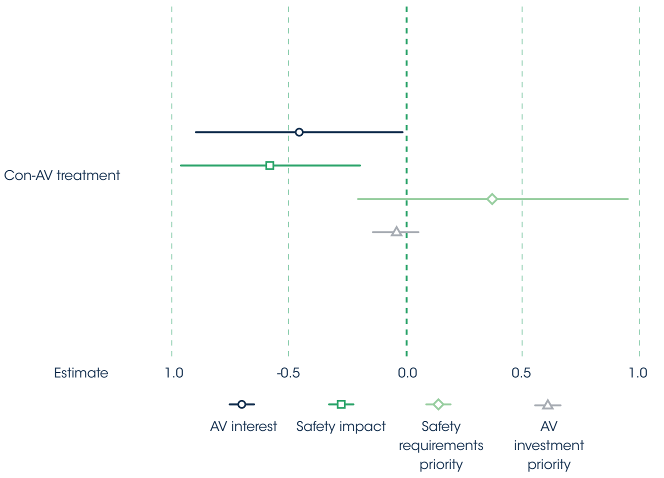
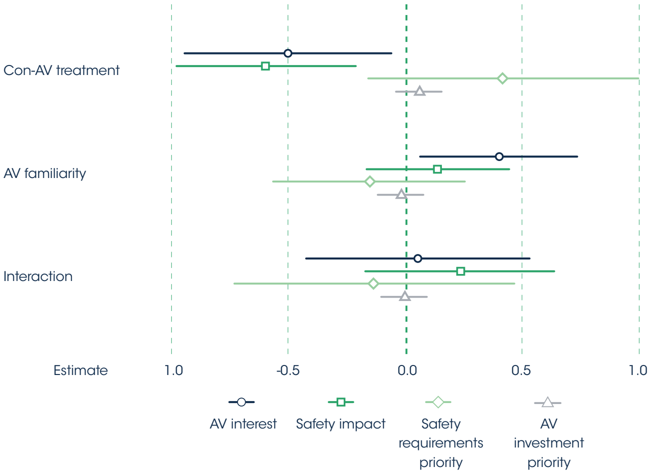


Figure 4-22. Con-AV treatment effects conditioning on AV familiarity



RIPTA driver experiment

As part of a collaboration between the research team and RIPTA, an additional experiment focused on perceptions of autonomous vehicles among professional transit drivers. Twenty-four public transit drivers who operate fixed-route public buses and variable-route paratransit vans participated in a study in July and August 2019. The sample was small due to logistical difficulties associated with surveying large groups of drivers in relation to hands-on exposure to an autonomous shuttle pilot program. The survey of public transit drivers was administered to small groups (three to five drivers per group) as a part of what was framed as a training opportunity during which they visited the public transit agency, received a briefing on the Little Roady pilot program, and rode in the autonomous shuttle vehicles.

During their shuttle rides, many drivers spoke with May Mobility safety operators regarding their experiences with the AV technology. The survey associated with this experience was designed as a two-stage panel survey, wherein drivers completed the same survey twice. First, they responded to survey questions on paper when they arrived at the transit agency. Second, they revisited the same paper survey (with a different color pen) after they were briefed on the pilot program and rode the shuttle. Asking the drivers to revisit the survey after riding the autonomous shuttle was intended to investigate whether having direct experience with automation technology influenced attitudes of workers whose jobs might be affected by those same technologies.

Three questions included on the transit driver survey were similar to the outcome items on the national survey, as they asked respondents to assess the impact of new technologies on their (a) productivity, (b) job satisfaction, and (c) job security. The two differences were in the specificity of the question and the scale used to measure responses. Whereas the national survey asked, "*In your current job or the job you most recently held, have new technologies and automation made the following better or worse?*" the transit driver survey asked, "*What impact do you think autonomous vehicle technologies will have on the following aspects of your work?*"

The transit driver survey asked participants to reflect on the specific impact of AV technologies in the future, whereas the national survey focused on the effects of technologies generally in the past. Furthermore, whereas the national survey used a five-point Likert scale (3 = *neutral*), the public transit driver survey used a seven-point Likert scale (4 = *neutral*) to be consistent with other questions. Additional questions on the transit driver survey focused on participants' assessments of the impact of autonomous vehicles on issues unrelated to the workforce, such as passenger safety and privacy. Drivers also estimated when AVs would become a *conventional transit option* and how they thought the government should prioritize a variety of regulatory issues, such as those related to safety and retraining public transit workers.

Findings: Public transit drivers reported mostly positive perceptions of autonomous vehicles both before and after riding in them. Moreover, public transit drivers became more positive about the potential impact of autonomous vehicles on various aspects of their work after riding the autonomous shuttles. For example, the share of transit drivers reporting that autonomous vehicles would have a negative impact on their job security decreased from 25% (5 drivers) to 10% (2 drivers). The share of drivers who predicted that autonomous vehicles would have a positive impact on their job security increased from 33% (8 drivers) to 67% (14 drivers). Drivers' perceptions of autonomous vehicles became more positive following their experiences, irrespective of their perceptions of the readiness of AV technology for widespread deployment. One potential explanation for drivers becoming more optimistic about autonomous vehicles after riding in the shuttles is that their experience in the shuttles suggested that the autonomous vehicle technology was not a viable replacement for their work.

However, when asked when autonomous vehicles would become a *conventional transit option,* drivers reported similar responses in the pre-shuttle and post-shuttle surveys. In the pre-shuttle survey, 43% of drivers reported that autonomous vehicles would become *conventional* in 10 years or fewer, and 41% of drivers indicated the same in the post-shuttle survey. Moreover, drivers who did not think that autonomous vehicles would become *conventional* within 10 years were similarly likely to report positive perceptions of autonomous vehicles as drivers who reported expecting that autonomous vehicles would become conventional in *more than 10 years*, *never*, or that they had *no idea*. ●

Table 4-1. Drivers' perceptions of future impacts of AVs on their work

Aspect of work	Negative impact	No impact	Positive impact
Pre-shuttle experience responses			
Productivity (*n* = 23)	9%	48%	43%
Job satisfaction (*n* = 23)	52%	39%	9%
Job Security (*n* = 24)	25%	42%	33%
Post-shuttle experience responses			
Productivity (*n* = 22)	0%	41%	59%
Job satisfaction (*n* = 22)	32%	32%	36%
Job Security (*n* = 21)	10%	24%	67%

Findings

4.3. Pilot Performance, Ridership, and User Behavior

4.3.1. Ridership Data

May Mobility AV shuttle, May 15, 2019–March 13, 2020

According to ridership data, the Little Roady pilot under operation of May Mobility served 42,206 unique rider trips, with ridership averaging 141 riders per operating day, defined here by the number of passengers that boarded shuttles across all of the stops on the Little Roady route (Figure 4-24). The highest single-day ridership was 241 passengers, and 48.16% of daily ridership values lie between 100 and 150 riders. Ridership data shows a general increase in ridership over the course of the pilot from average ridership in the first month (May 15 through June 15, 2019) of operations at 109 riders per day, to an average daily ridership of 175 per day in the last month of May Mobility operations (February 13 through March 13, 2020).

Plotting ridership on a weekly (Monday through Sunday), as well as monthly basis further demonstrates the overall increase in ridership across the pilot period, with specific periods of higher variability where ridership decreased (Figure 4-23). While overall average weekly ridership was 959 riders, weekly ridership increased from 582 riders per week in the first month to 875 riders per week in the last month of May Mobility operation. The sharp drop in monthly ridership in March 2020 coincides with the end of May Mobility service in mid-March.

RIPTA Shuttle service, March 16–June 30, 2020

Following May Mobility's decision to end Little Roady shuttle operations in March 2020, RIPTA resumed services on the Little Roady route and continued operations in place of May Mobility until the end of the originally planned pilot period in

Figure 4-23. Overall weekly ridership (Total passengers boarded, May Mobility and RIPTA shuttles) (*link*)

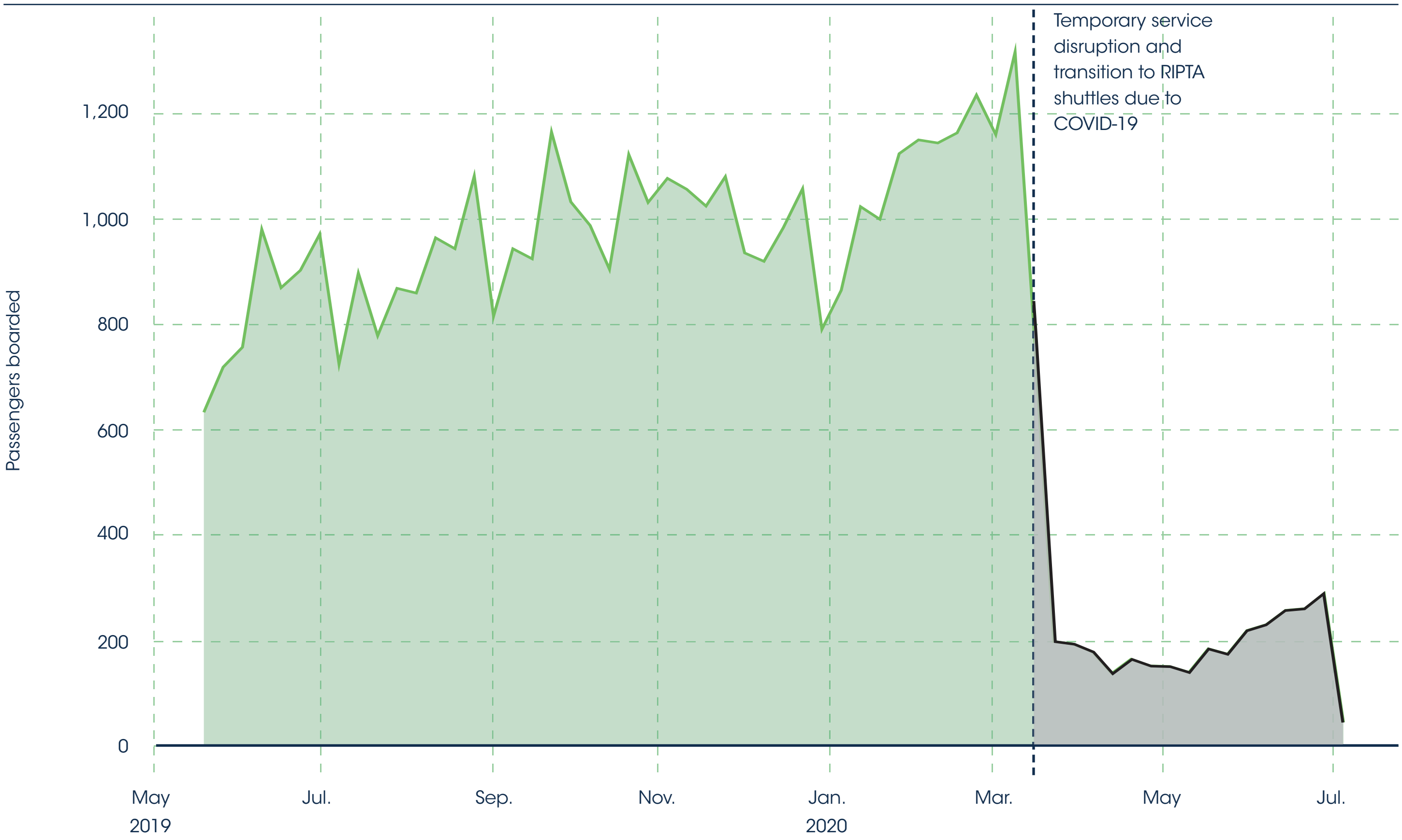


Figure 4-24. Daily ridership (Total passengers boarded, May Mobility shuttle) (*link*)

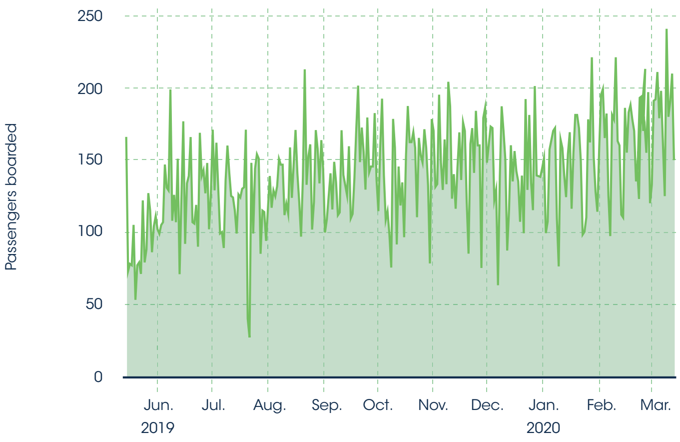


Figure 4-25. Daily ridership (Total passengers boarded, RIPTA shuttle) (*link*)

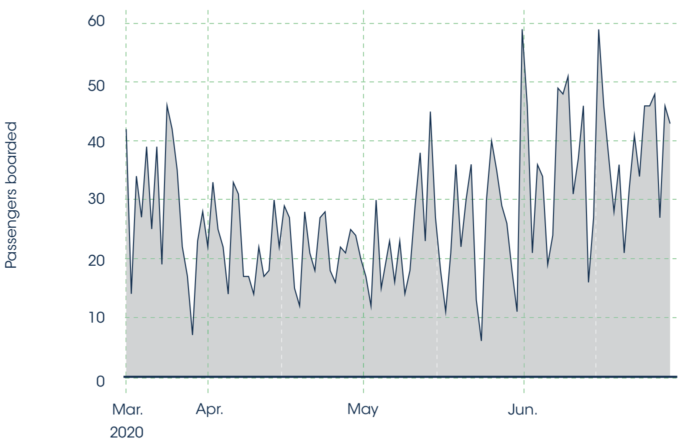


Figure 4-26. Monthly ridership (Total passengers boarded, May Mobility shuttle) (*link*)

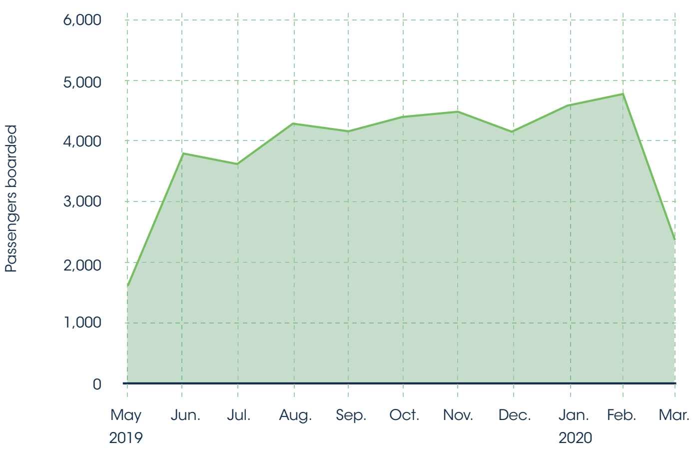
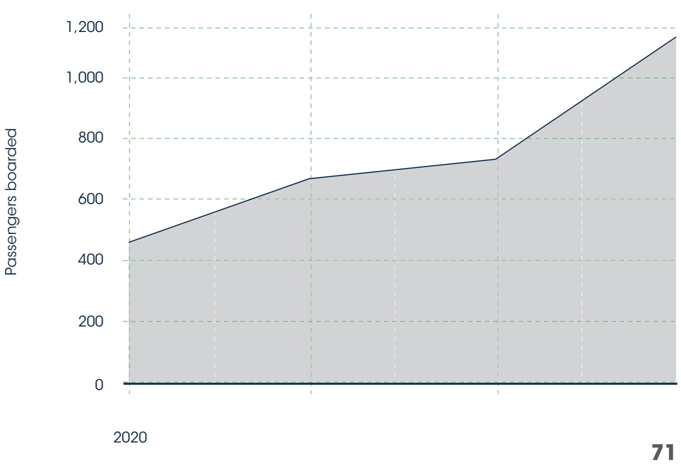


Figure 4-27. Monthly ridership (Total passengers boarded, RIPTA shuttle) (*link*)



June 2020. Ridership on the RIPTA-operated conventional shuttle was starkly lower than the May Mobility shuttles, with average weekly riders at 176 compared to 959 under May Mobility. Figure 4-23 demonstrates combined weekly ridership for both services, including the sharp decrease in ridership that occurred following the transition from May Mobility to the RIPTA Shuttle in March 2020. While the change in ridership corresponds with a short pause in service followed by notable changes in service provisions, this time period was also marked by drastic public and private responses to COVID-19-related conditions, including shelter-in-place mandates.

Weekly ridership trends for the RIPTA Shuttle portion of the shuttle pilot reveal an overall increase in ridership during this period, which could relate to phased re-openings. However, the RIPTA Shuttle maximum weekly ridership peaked at 288 riders compared to 1,318 riders prior to COVID-19, and average daily ridership for the period was 28 riders, compared to 141 under May Mobility.

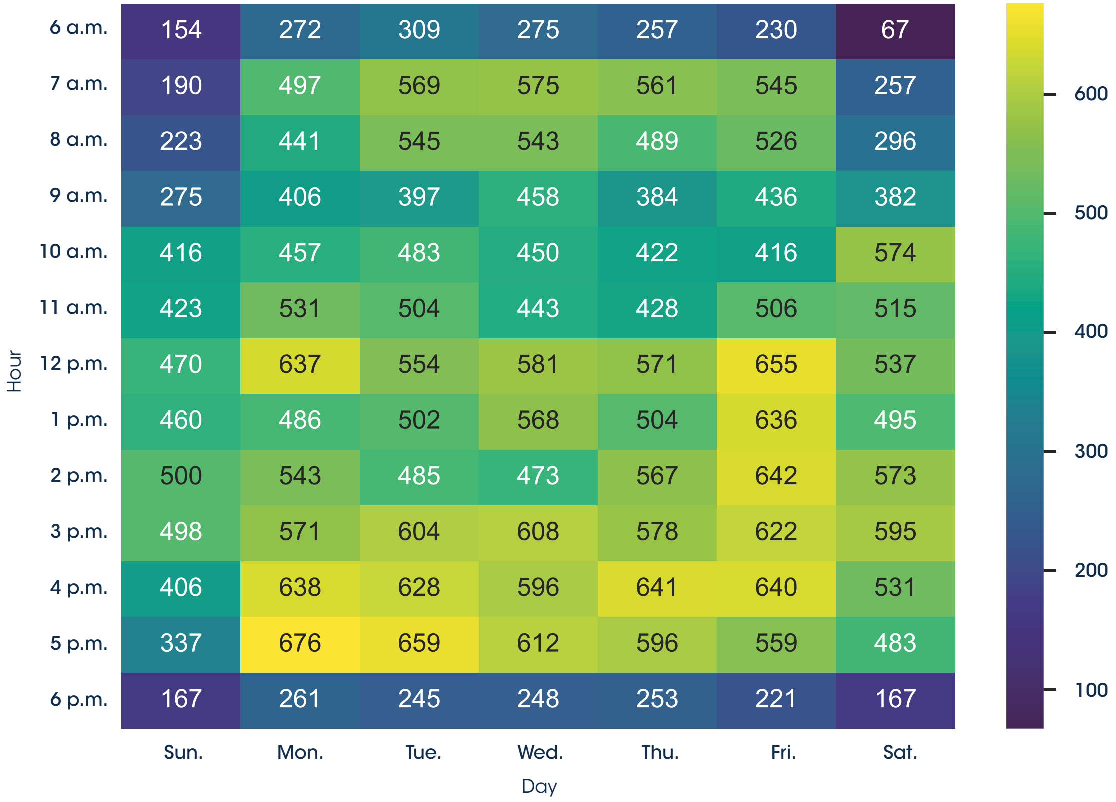
Ridership by stop and by hour, May Mobility shuttle

The number of passengers boarding and alighting the Little Roady shuttle across each of its 12 stops can shed light on how riders used the shuttle service. The variable total passenger activity indicates that the Olneyville Square and Providence Station stops, which were the terminal stops, accounted for the highest overall activity (17,671 and 23,313 cumulative passengers boarding and alighting, respectively). However, Olneyville Square had far more passengers boarding (10,112) compared to alighting (7,559), whereas Providence Station was much more balanced between passengers boarding (10,392) and alighting (12,921) (Table 4-3). Total passenger activity for other stops ranged between 817 (Kinsley/Acorn) and 8,106 (Eagle Square/US Rubber [Northbound]).

Figure 4-28 is a heat map that illustrates cumulative riders entered per hour and per day across all shuttle stops. Highest ridership typically occurred on weekdays between 4:00 and 6:00 p.m., but Friday afternoons had the most

Figure 4-28. Total ridership by hour (all service days) (May Mobility shuttle) (*link*)

Note: The Little Roady shuttle service began at 6:30 a.m. and concluded at 6:30 p.m. Therefore, the lower ridership values associated with the first and last hours of service on the heat map below can be partially attributed to this.



Hour	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
6 a.m.	154	272	309	275	257	230	67
7 a.m.	190	497	569	575	561	545	257
8 a.m.	223	441	545	543	489	526	296
9 a.m.	275	406	397	458	384	436	382
10 a.m.	416	457	483	450	422	416	574
11 a.m.	423	531	504	443	428	506	515
12 p.m.	470	637	554	581	571	655	537
1 p.m.	460	486	502	568	504	636	495
2 p.m.	500	543	485	473	567	642	573
3 p.m.	498	571	604	608	578	622	595
4 p.m.	406	638	628	596	641	640	531
5 p.m.	337	676	659	612	596	559	483
6 p.m.	167	261	245	248	253	221	167

Table 4-2. Little Roady ridership, passengers boarded

	N	Mean	Std. dev.	Min.	Max.
May Mobility shuttle – Daily	299	141.16	35.08	27	241
May Mobility shuttle – Weekly	44	959.23	159.79	552	1,308
May Mobility shuttle – Monthly	11	3,836.91	986.45	1,611	4772
RIPTA shuttle – Daily	107	27.97	11.55	6.00	59.00
RIPTA shuttle –Weekly	17	176.06	66.81	42.00	288.00
RIPTA shuttle – Monthly	4	748.25	244.53	459	1134
Overall – Monthly	14	3,267.00	1,474.00	668.00	4,785.00

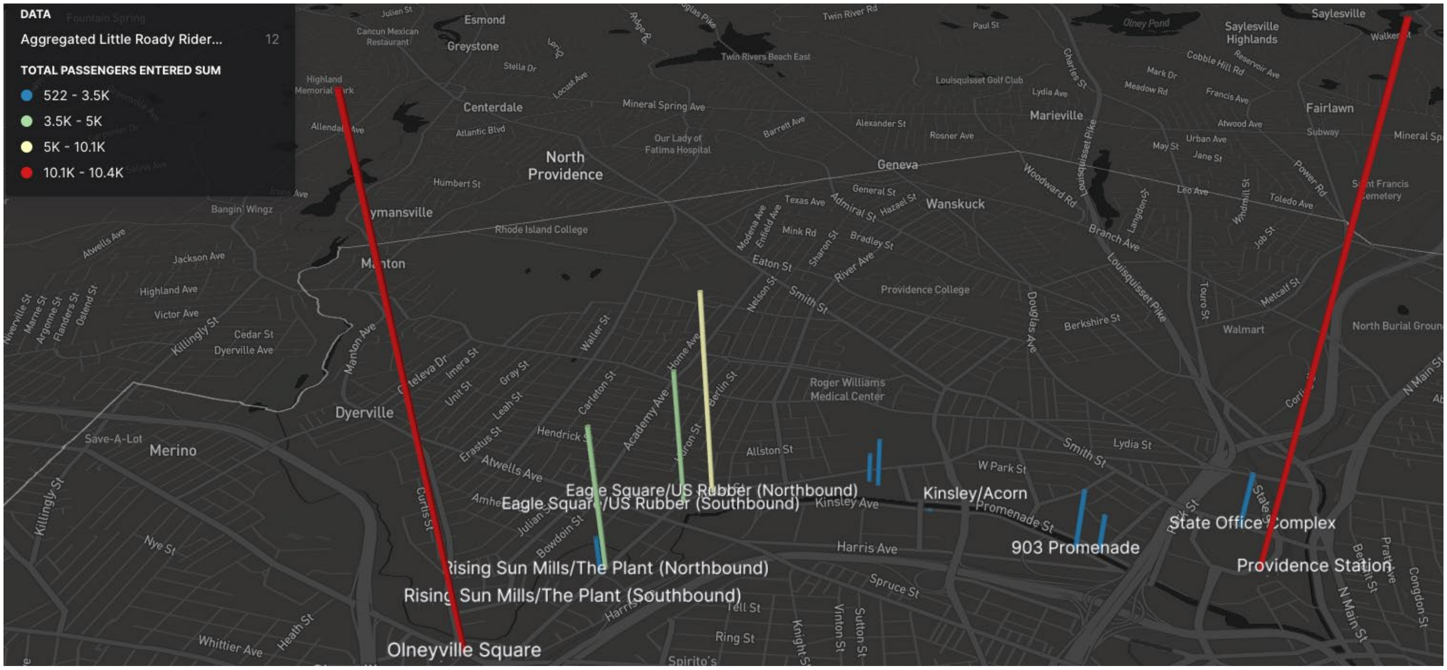
Table 4-3. Total ridership by stop (May Mobility shuttle)

	Passengers boarded	Passengers alighted	Net passengers	Total passengers activity
State Office Complex	1,750	2,285	-535	4,035
Foundry/Promenade	1,333	1,068	265	2,401
ALCO (WB)	1,158	1,779	-621	2,937
Eagle Square/US Rubber (SB)	3,518	4,450	-932	7,968
Rising Sun Mills/The Plant (SB)	1,329	1,560	-231	2,889
Olneyville Square	10,112	7,559	2,553	17,671
Rising Sun Mills/The Plant (NB)	3,658	782	2,876	4,440
Eagle Square/US Rubber (NB)	4,967	3,139	1,828	8,106
ALCO (EB)	1,597	888	709	2,485
Kinsley/Acorn	522	295	227	817
903 Promenade	1,870	1,787	83	3,657
Providence Station	10,392	12,921	-2,529	23,313

Passengers boarded: Total passengers entered the Little Roady AV shuttle at a given stop
Passengers alighted: Total passengers exited the Little Roady AV shuttle at a given stop

Net passengers: Total passengers entered minus total passengers exited
Total passengers activity: Total passengers entered plus total passengers exited

Figure 4-29. Total passengers boarded, by stop (May Mobility shuttle) (*link*)



consecutive high demand hours. Nonetheless, ridership was rarely below 400 riders per hour time slot other than early weekend mornings.

4.3.4. Performance Data: Little Roady AV shuttle

Mileage and average vehicles deployed

Total miles traveled per month along the 5.3-mile route by the Little Roady AVs shuttle was calculated by merging stop-level shuttle time stamps with line segments between stops to calculate distances traveled. Doing so allows accounting for events in which shuttle vehicles skipped stops or reversed routes to go back to one stop. As such, decreases in miles traveled on a monthly basis could be associated with multiple factors, including service reductions or disruptions, while increases in miles traveled could be associated with additional vehicles in operation or irregular trips, making interpretation of these values in isolation challenging.

Nonetheless, it is notable that average miles per month was 10,640 miles, with 117,042 miles total traveled across the entirety of the Little Roady AV shuttle pilot (Figure 4-30). Reduction in monthly distances are generally attributable either to partial operation (May 2019 and March 2020) and reductions in vehicles deployed (June and July 2019).

According to reports from May Mobility to RIDOT, the contractual Service Level Agreement (SLA) called for the deployment of six vehicles during on-peak periods (6:30–10:30 a.m. and 2:30–6:30 p.m.) and four vehicles during off-peak periods (10:30 a.m.–2:30 p.m.) during operating hours of the Little Roady shuttle.

To estimate the frequency at which these SLA goals were met, the number of unique vehicles deployed was calculated in 15-minute intervals during all hours of expected service operation. Figure 4-30 illustrates that the months of July and August 2019 were the lowest performing in terms of SLA compliance (Figure 4-31). The low SLA performance in the summer of 2019 aligns with an array of technical and operational challenges associated with the shuttle. Monthly reports often framed reduction of vehicles "due to maintenance and charging needs" (May Mobility, 2019c).[1]

The lack of a satisfactory response from May Mobility on these ongoing technical and operational issues prompted RIDOT action to rectify the situation. On August 9, 2019, RIDOT sent May Mobility a breach of contract letter based on their failure to meet a number of requirements, including failure to provide a handicap accessible autonomous vehicle, air conditioning on the shuttles, and timely submission of detailed monthly reports.

While the number of vehicles in operation at any given time is a valuable metric for interpreting the status of shuttle operations, another key indicator is headways (i.e., the interval of time, in minutes, between shuttles operating on the route).

In their initial service plan, May Mobility targeted wait times of less than 10 minutes, and average headways across the operating period of the Little Roady AV shuttle met this goal with an average of 8.61 minutes (Figure 4-32) (May Mobility, 2019b). A review of headways over time, however, reveals a significant increase in headways during summer 2019 aligned with the aforementioned service reliability issues.

Passengers left waiting

The number of passengers left waiting at stops can serve as an indicator of the degree to which the shuttle service was unable to meet demand at a particular location. Providence Station had the highest cumulative total of passengers left waiting, followed closely by Eagle Square/ US Rubber (northbound) (Table 4-6). When viewed relative to hours of the day and days of the week, ridership demand outweighed vehicle capacity most often during mid-day hours (e.g., 1:00–2:00 p.m. on Wednesdays, and 12:00–1:00 p.m. on Fridays). However, the cumulative total of passengers left waiting (312) relative to total rides (42,206[2]) accounts for 0.74% of potential riders left waiting, which is an indication that the shuttle generally ran far under capacity.

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[1] See section 5.3.1. for additional technology and infrastructure details and discussion.

[2] This is the value generated when summing the passengers boarded variable in the stops data from the May Mobility API. The passengers exited variable sum gives a different number (38,513). Because ridership values were counted manually, the research team assumes the passengers boarded variable is more reliable.

Figure 4-30. Total miles traveled, by month

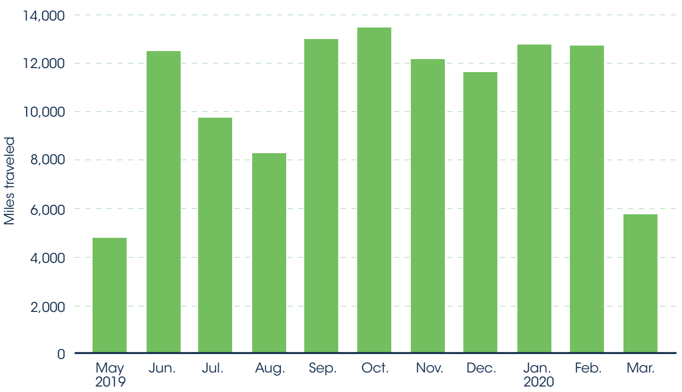


Figure 4-31. Average vehicles deployed by week (15-min. intervals)

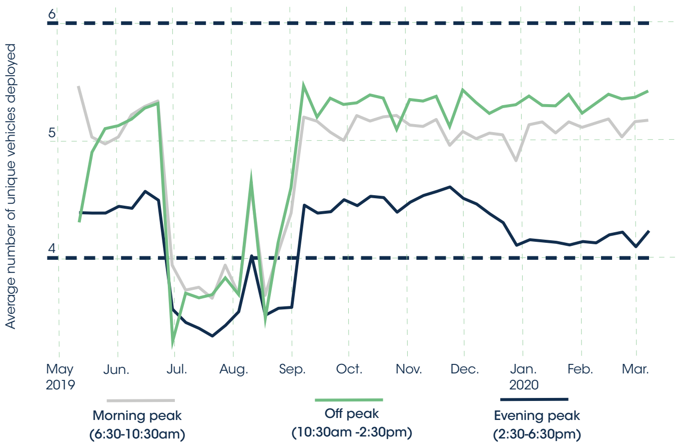


Figure 4-32. Daily average route-wide headways (*link*)

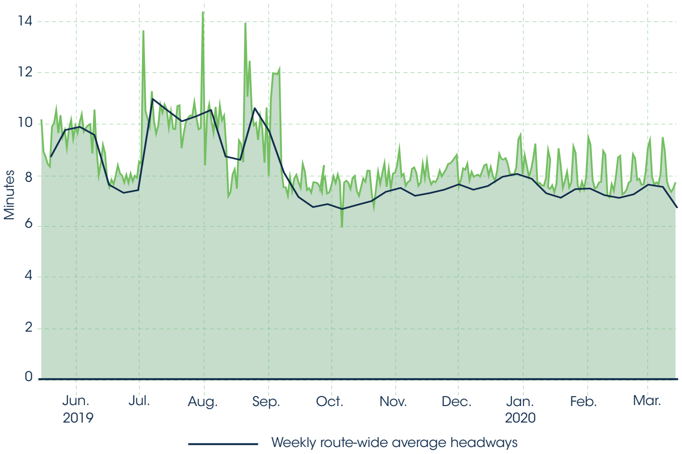
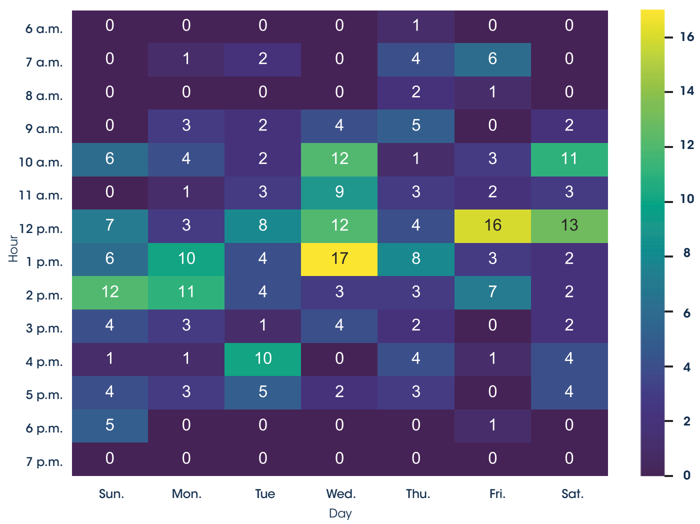


Figure 4-33. Total riders left curbside, by day and time (*link*)



Hour	Sun.	Mon.	Tue	Wed.	Thu.	Fri.	Sat.
6 a.m.	0	0	0	0	1	0	0
7 a.m.	0	1	2	0	4	6	0
8 a.m.	0	0	0	0	2	1	0
9 a.m.	0	3	2	4	5	0	2
10 a.m.	6	4	2	12	1	3	11
11 a.m.	0	1	3	9	3	2	3
12 p.m.	7	3	8	12	4	16	13
1 p.m.	6	10	4	17	8	3	2
2 p.m.	12	11	4	3	3	7	2
3 p.m.	4	3	1	4	2	0	2
4 p.m.	1	1	10	0	4	1	4
5 p.m.	4	3	5	2	3	0	4
6 p.m.	5	0	0	0	0	1	0
7 p.m.	0	0	0	0	0	0	0

Table 4-6. Headways and riders left curbside, overall

	Headways (min.)		Riders left waiting
Station	**Mean**	**Median**	
State Office Complex	8.56	7.386	42
Foundry/Promenade	8.653	7.445	16
ALCO (WB)	8.504	7.329	22
Eagle Square/US Rubber (SB)	8.987	7.543	37
Rising Sun Mills/The Plant (SB)	9.147	7.98	9
Olneyville Square	7.308	6.059	35
Rising Sun Mills/The Plant (NB)	9.327	7.984	12
Eagle Square/US Rubber (NB)	8.63	7.396	58
ALCO (EB)	8.592	7.393	5
Kinsley/Acorn	8.661	7.639	4
903 Promenade	8.731	7.634	9
Providence Station	6.675	5.397	63

Table 4-4 Total miles traveled, by month

	Mean	Std. dev.	Min.	Max.
Miles	10,640	3,069	4,797	13,511

Table 4-5 Overall route-wide headways

	Count	Mean	Std. dev.	Min.	Max.
Daily	298	8.61	1.23	5.95	14.4
Weekly	44	8.56	0.95	7.5	10.74

Trip duration

Overall trip duration was relatively normally distributed (*Median* = 41.38 minutes), once accounting for outliers in the data. Half-trips from the State Office Complex to Olneyville Square had a median duration of 17.61 minutes, whereas return half-trips from Olneyville Square to the State Office Complex had a median trip time of 20.59 minutes (Figure 4-34). The data from May Mobility was not constructed in a manner to generate these values with high confidence, so outliers are retained in the data set and included in the figures.

Service disruptions

In addition to many instances wherein service was reduced due to a number of factors, May Mobility reported five instances in which service was suspended altogether, which May Mobility indicated were the result of high heat in summer months and snow in the winter. In their August 2019 monthly report, May Mobility stated

> *"The largest insight we took this month was how to keep a fleet running. We attempted numerous upgrades on our vehicles through July and August, in addition to replacing sensors and actuators as during normal operation. This caused a backlog of vehicles that were grounded (unable to operate at all) or manual only (unable to operate in autonomy – likely due to sensor issues). This affected operations through all of August." (May Mobility, 2019c)*

Additionally, the abrupt ending of Little Roady shuttle service in mid-March 2020 resulted in two days of interrupted service before the replacement RIPTA shuttle service came online, resulting in a total of 42.5 hours of service suspension, not including holidays (Table 4-7).

Table 4-7. Service suspensions*

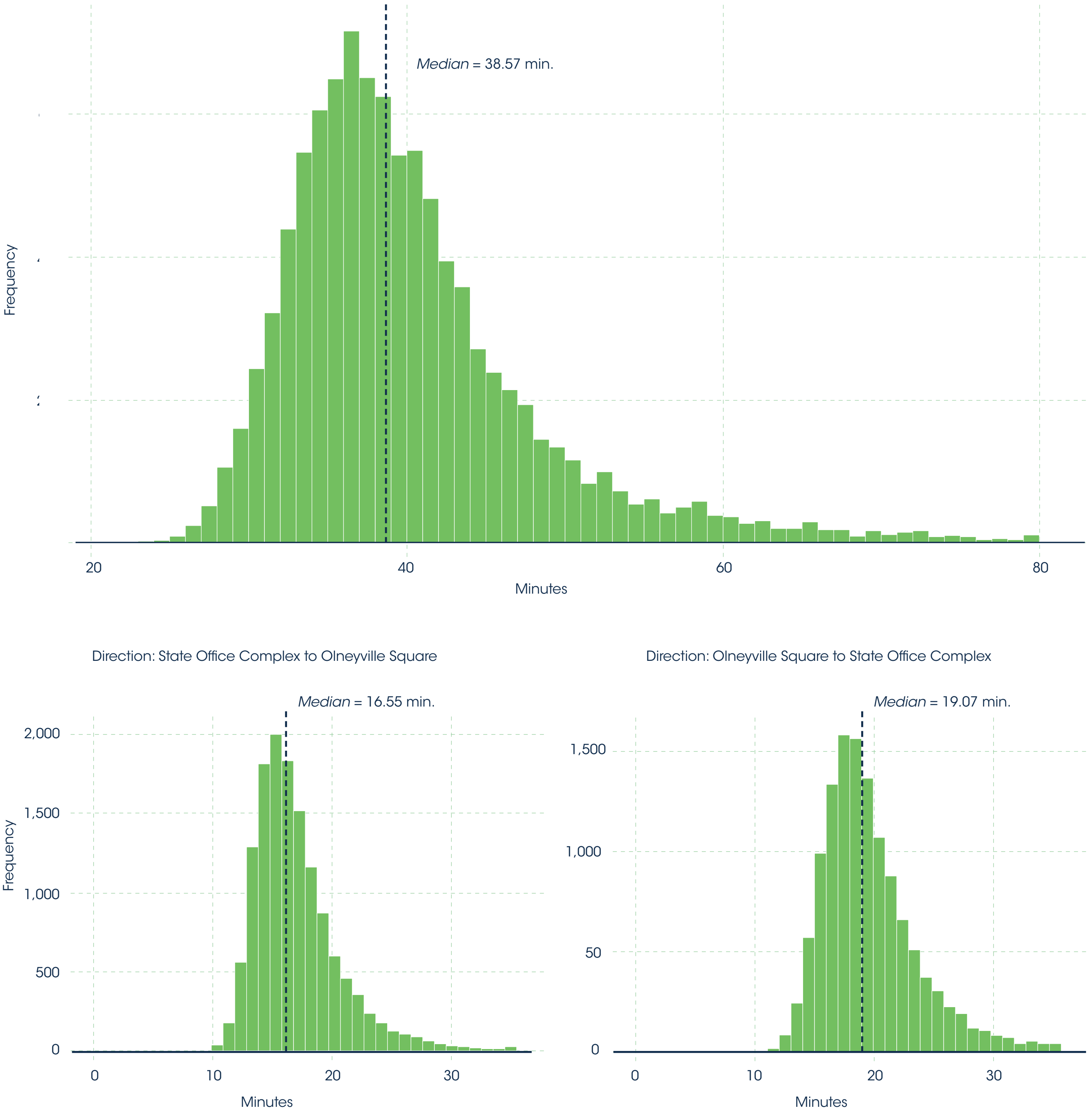
Date	Hours suspended (out of 12)	Category	Description
July 20, 2019	6.5	High heat	"Due to the heat index reaching 100, we will be stopping service." (May Mobility, 2019b)
July 21, 2019	8	High heat	"Due to the heat index reaching 100, we will be stopping service." (May Mobility, 2019b)
July 30, 2019	4	High heat	"Due to the heat index reaching over 100 degrees, we have stopped service." (May Mobility, 2019b)
August 19, 2019	2.5	High heat	"Due to high battery temperature and high heat index, we stopped service." (May Mobility, 2019c)
December 3, 2019	5.5	Snow	"Due to snow, we operated from 12pm–6:30p.m." (May Mobility, 2019f)
March 14, 2020	8	Service Closure	Two-day gap before RIPTA Shuttle begins to compensate
March 15, 2020	8	Service Closure	Two-day gap before RIPTA Shuttle begins to compensate
Total	42.5		

**Not included are no service days for Labor Day, Thanksgiving, Christmas, and New Year's. Labor Day was not defined as a holiday by contract, but May Mobility erroneously did not operate service on that day.*

Table 4-8. Trip duration (minutes)

	Count	Mean	Median	Std. dev.	Min.	Max.
Round trip	16,926	40.46	38.57	8.92	8.92	160.97
State Office Complex to Olneyville Square	13,974	17.61	16.55	5.00	5.00	92.93

Figure 4-34. Trip duration (minutes)



Incidents

May Mobility reported 14 incidents over the course of the Little Roady AV shuttle pilot. For analytical purposes, incidents are classified according to determinations by May Mobility related to (a) apparent cause (*operator error*, *other driver*, or *other*) and (b) autonomy status at the time of incident (*manual mode* or *AV mode*), along with the nearest intersection (Table 4-9 and Figure 4-37).

Eight of the 14 incidents involved the May Mobility shuttle being struck by another vehicle while the shuttle itself was not moving or at an intersection (in both manual and AV modes). The remaining six incidents involved a combination of fleet attendant error in manual mode (e.g., hitting a curb, crashing into a fence, rear ending a parked vehicle), a mechanical breakdown, and being struck by a cyclist. According to traffic incident data available from RIDOT, only one incident was classified as including a possible injury. Nearly all incidents occurred in dry conditions and all during daylight hours.

The months within which multiple incidents occurred were June 2019 (*n* = 2), December 2019 (*n* = 4), January 2020 (*n* = 3), and February 2020 (*n* = 2). See Appendix B for further incident details, as reported by May Mobility.

Figure 4-35. Incident locations (*link*)

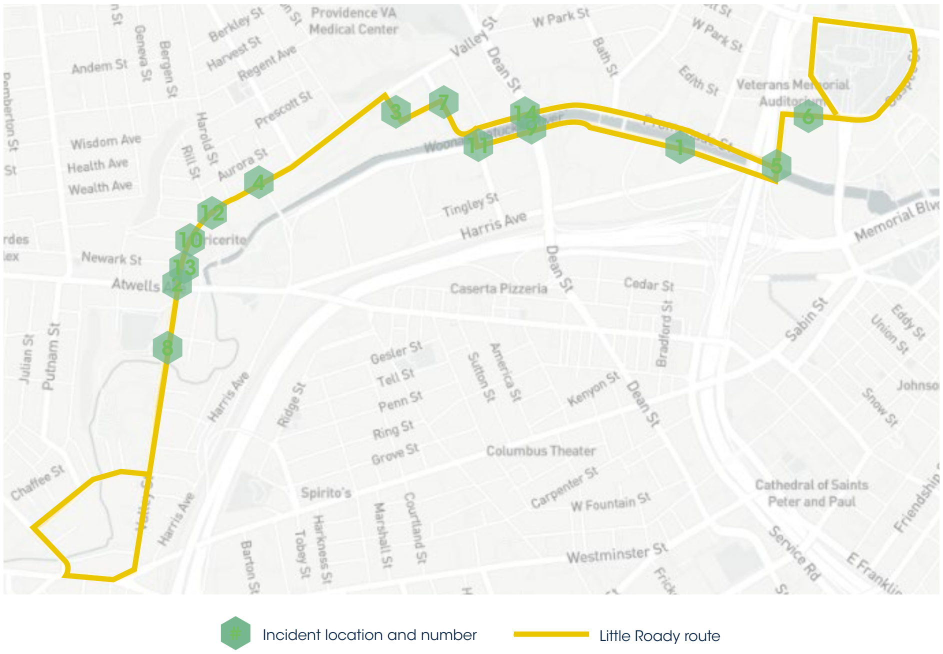


Figure 4-36. Incidents over time (*N* = 14)

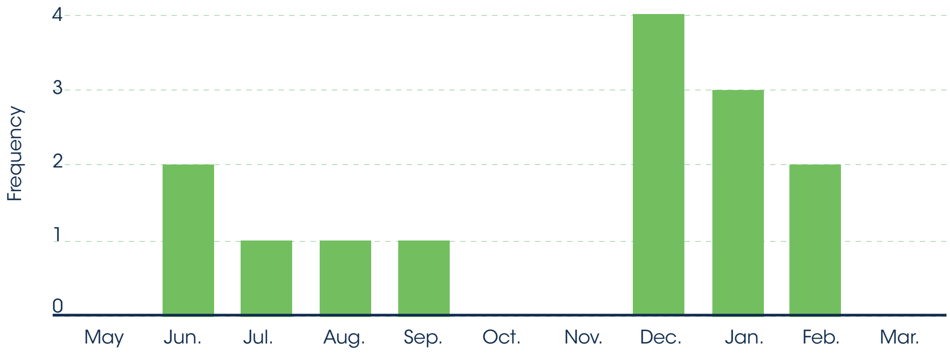


Figure 4-37. Incident classifications (*N* = 14)

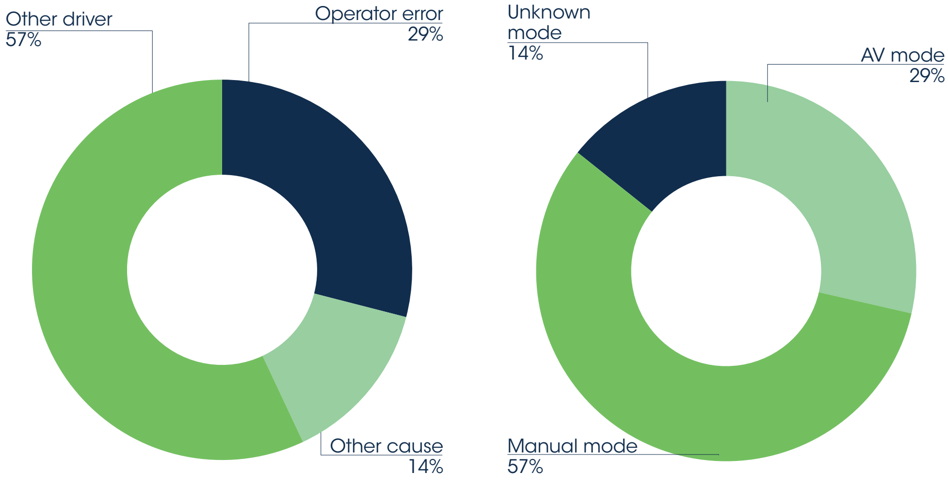


Table 4-9. Incident details*

#	Date	Time	Intersection	Description	Mode	Cause	Direction	Light	Weather	Road	Traffic	Collision type	Person
1	6/12/2019	6:24 p.m.	Providence Pl at the Providence Place stop	May Shuttle was side swiped by another vehicle.	AV	Operator Error	Eastbound	Daylight	Clear	Dry	No Controls	Sideswipe, Same Direction	2 No Apparent Injury
2	6/13/2019	4:32 p.m.	Valley and Atwells	May Shuttle was rear ended at Valley and Atwells.	Manual	Other Driver	Northbound	Daylight	Cloudy	Wet	Traffic Control Signal	Rear End (Front-to-Rear)	1 No Apparent Injury
3	7/1/2019	2:53 p.m.	Ironhorse Way WB (Alco WB stop)	Single vehicle accident. May Shuttle hit the curb at Alco in manual mode. Fleet Attendant reported he blacked out at the t-bar and struck the curb head-on.	Manual	Operator Error							
4	8/9/2019	10:50 a.m.	Intersection at Eagle and Valley	May Shuttle made a hard stop at a yellow light turning red. A trailing vehicle rear ended the May Shuttle. The FA trainee was brought to the hospital by ambulance and was cleared by a doctor later that day. The light turned yellow with shuttle crossing over white line of intersection, leading to a hard stop. A Kia SUV rear ended the May Shuttle while following closely.	AV	Other Driver	Westbound	Daylight	Clear	Dry	Traffic Control Signal	Rear End (Front-to-Rear)	1 Possible Injury, 3 No Apparent Injury
5	9/28/2019	6:03 p.m.	Park St. NB	May Shuttle was lightly rear ended by a vehicle that immediately drove off. A manual transmission Mazda behind the shuttle was rolling back and forth. At one point, as the vehicle was rolling forward, it lightly hit the May Shuttle. The driver of the Mazda pulled up next to the May Shuttle, and fleet attendant let them know they hit the shuttle and should pull over. Instead the driver drove away. Two passengers were in the vehicle at the time. Very little damage done to the shuttle.	Manual	Other Driver							
6	12/1/2019	5:08 p.m.	Providence Place Mall North Entrance (Hayes St)	A vehicle ahead of the May shuttle drove in reverse to let another vehicle ahead get around. The driver backed into shuttle. The May Shuttle was at complete stop at the time. The driver of the other vehicle drove away before information could be gathered.	Manual	Other Driver							
7	12/8/2019	5:00 p.m.	Hemlock and Promenade	Single vehicle crash with metal fence at Hemlock and Promenade; damage to the front passenger side of May shuttle.	Manual	Operator Error							
8	12/15/2019	3:45 p.m.	Outside 221 Valley St.	Fleet attendant rear ended a parked Honda Odyssey on Valley Street.	Manual	Operator Error	Southbound	Daylight	Clear	Dry	No Controls	Not a Collision Between Two	1 No Apparent Injury
9	12/20/2019	12:13 p.m.	Kinsley Ave and Dean St intersection	May Shuttle lost steering capability while beginning to cross the intersection. The fleet attendant avoided incident by slowing the vehicle to a stop as it approached the curb on the left side of the street at the far end of the intersection (Kinsley is a one-way during this stretch). The regular braking system was fully operational during this time.	Manual	Other							
10	1/7/2020	10:43 a.m.	Valley and Turner (Eagle Square stop)	Vehicle was parked at Eagle Square stop when it was rear ended by an elderly female. The woman was incoherent, and an EMT arrived on scene and took over. The police noted this.	AV	Other Driver	Southbound	Daylight	Clear	Dry	No Controls	Rear End (Front-to-Rear)	2 No Apparent Injury
11	1/9/2020	10:35 a.m.	Acorn and Kingsley	The May Shuttle was at a stop sign when it was rear ended by another vehicle. The other vehicle immediately left the scene.	Unknown	Other Driver	Northbound	Daylight	Clear	Dry	Stop Signs	Rear End (Front-to-Rear)	1 No Apparent Injury
12	1/10/2020	7:30 a.m.	US Rubber stop	May Shuttle was stopped at the US Rubber stop. Another vehicle drove too close and hit and damaged the May Shuttle mirror. The other vehicle did not stop and left the scene.	AV	Other Driver	Eastbound	Daylight	Clear	Dry	No Controls	Sideswipe, Opposite Direction	1 No Apparent Injury
13	2/25/2020	8:26 a.m.	Southbound Valley Street at Atwells	Shuttle was stopped at a red light. When the light turned green it was rear ended by another vehicle before it began to accelerate. The other vehicle remained on the scene.	Unknown	Other Driver	Westbound	Daylight	Clear	Dry	No Controls	Rear End (Front-to-Rear)	3 No Apparent Injury
14	2/26/2020		Promenade and Dean	Shuttle was in route when a bicyclist made impact with the right panel of the vehicle. Bicyclist gave information but left the scene.	Manual	Other							

**Incident dates, locations, descriptions, and classifications are drawn from May Mobility reports. Other data merged from RIDOT Traffic Research Unit reports, where available.*

Autonomous vehicle mode versus manual mode

One of the key aspects of interest related to operation of the Little Roady AV shuttle relates to the balance between the shuttle's operation in AV mode versus manual mode, in terms of distance and duration, and the reasons for automated and manual switching between modes. According to May Mobility, AV mode use increased considerably throughout the duration of the pilot as a result of a number of factors (Figure 4-38). Unfortunately, the annotated heat maps were the highest level of granularity provided by May Mobility related to distance traveled and portions of the route typically operated in AV versus manual modes.

While narratives included in May Mobility reports are illustrative, lack of granular data precludes the possibility of independent analysis and interpretation, thereby limiting the degree to which these conclusions can be interpreted with confidence. As a result, this section relies heavily on observational data from field researchers in an effort to capture lessons about the successes and challenges associated with AV operations. As these observations are drawn from a limited set of field work, the resulting findings are not as robust as they could have been had more granular data been made available by May Mobility to the research team. See the discussion and conclusion sections for further details.

According to May Mobility, typical early reasons for enforced and fleet attendant-engaged manual mode included unprotected left turns, construction zones, and heavy traffic, whereas high autonomy mode was associated with areas of the route with fewer traffic lights, pedestrians, and lower speed limits. May Mobility's monthly reports over the course of the pilot describe an iterative process of identifying and attempting to resolve a variety of issues related to AV mode. Some specific examples include the limited turning radius of the GEM e6 vehicles requiring manual mode to maneuver into tight spaces (May Mobility, 2019c); the LiDAR system interpreting thick grass as a solid object, thereby aggravating the system's short-range emergency stop system (May Mobility, 2019c); and lane changes requiring updates to the internal maps (May Mobility, 2019d).

Monthly reports often cited general software updates and refinements to the semantic map that underpins on-route behaviors of AV mode as key determinants of increased use of AV mode. Updates to the semantic map were often based on real-world observations of traffic patterns and were often carried out to increase accuracy and account for changes in road conditions (e.g., repainted or altered lane and crosswalk geometry) (May Mobility, 2019e). Near the conclusion of the project, May Mobility reported that

> *"Some segments of the Little Roady route have shown dramatic change month-over-month, while most or all of the remainder of the route has shown a slight increase in the rate of autonomy utilization as fleet attendants become more confident in the May Mobility autonomy system and continued training reinforces good habits. The improvement also reflects stability in road conditions and lack of obstruction by construction and traffic shifts."* (May Mobility, 2020, p. 22)

The included autonomy mode heat maps in Figure 4-38 demonstrate an apparent overall increase in the use of AV mode throughout the course of the pilot. However, in the absence of either raw data and clear definitions of the means by which these heat maps and associated color-coded scales are generated, they cannot be interpreted definitively.

Field observations of Little Roady shuttle operations indicate a wide range of reasons for which drivers apparently switched from AV to manual mode, with unprotected turns (29.6%), heavy traffic (10.8%), and other driver behavior (12.3%) as the most common apparent reasons (Figure 4-39). Examples of other driver behavior include emergency vehicles passing by, bicycle riders close to the shuttle, and vehicles in bicycle lanes.

Field researchers also attempted to record the number of minutes Little Roady shuttles remained in AV mode during a given observation period. Notably, 168 out of 424 (40%) of observed routes were run entirely in manual mode, and the average amount of time spent in AV mode (6.15 minutes from RIDOT to Olneyville Square and 4.91 minutes from Olneyville Square to RIDOT), accounts for less than one-third of the overall average half-route trip durations, based on data from May Mobility (Figures 4-40 and 4-41). The reasons for the apparent high number of non-autonomous routes and the low relative portion of routes run in AV mode are unclear. Weather conditions—rain, in particular—and equipment problems were often noted by field researchers as the rationales for enforced manual mode,

Figure 4-38. Monthly AV mode utilization heat maps as provided by May Mobility (May 2019–March 2020)

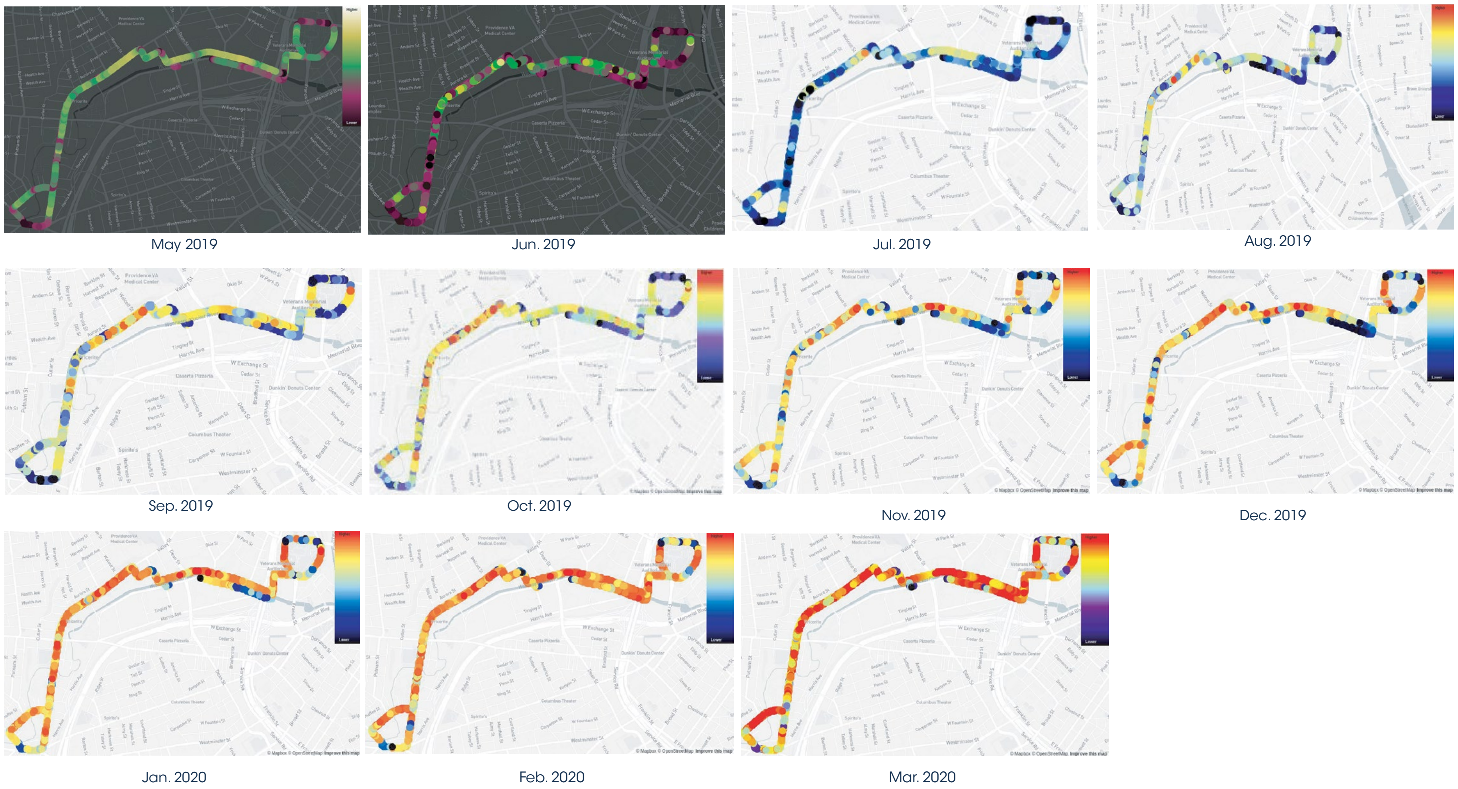
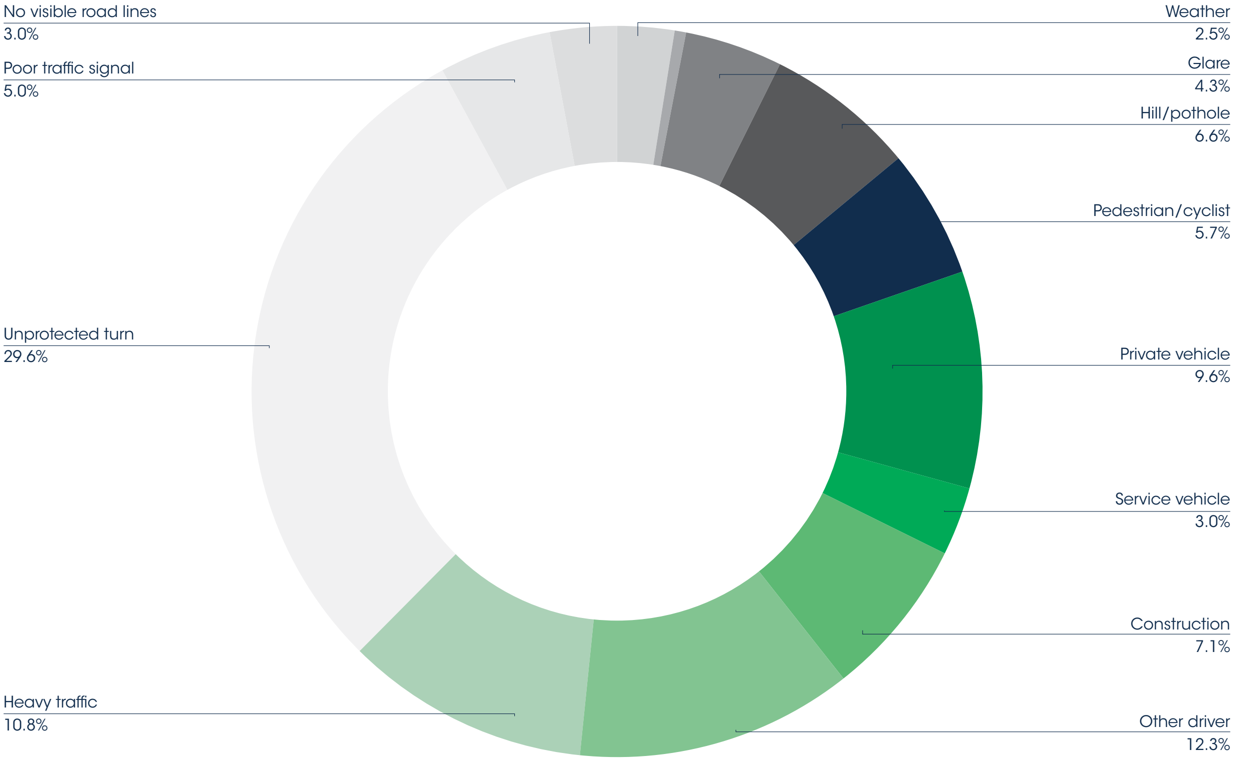

May 2019 Jun. 2019 Jul. 2019 Aug. 2019
Sep. 2019 Oct. 2019 Nov. 2019 Dec. 2019
Jan. 2020 Feb. 2020 Mar. 2020

Figure 4-39. Observed reasons for AV to manual mode shift (*N* = 434 route observations, May 2019–March 2020) (*link*)



but field researchers also noted ambiguity about when and why AV mode was not used. The following quotations are drawn from field researcher observations:

> ***"There are some shuttles that never go into autonomous mode and I think are just gathering data from my understanding based on conversations with [fleet attendants]."***

> ***"[The fleet attendant] mentioned each vehicle has its own personality. He also said not all vehicles are in autonomy and people who have been working longer have first priority."***

> ***"[The fleet attendant] said [the vehicle's] autonomous mode hasn't been working for the past few weeks."***

> ***"[The fleet attendant] said the shuttle was only in manual mode because it needed software updates."***

These field-based observations are considerably limited as they are drawn from a non-random sample of route observations, can be difficult to capture accurately, and are not generated automatically by May Mobility. They do, however, point to a wide range of potential conditions in which AV mode was not used during the pilot. See section 5.3.1. for additional technology and infrastructure details and discussion. ●

Figure 4-40. Histogram of observed minutes in AV mode per one-way (half) route observation period, from RIDOT to Olneyville Square (*N* = 207 observations, May 2019–March 2020) (*link*)

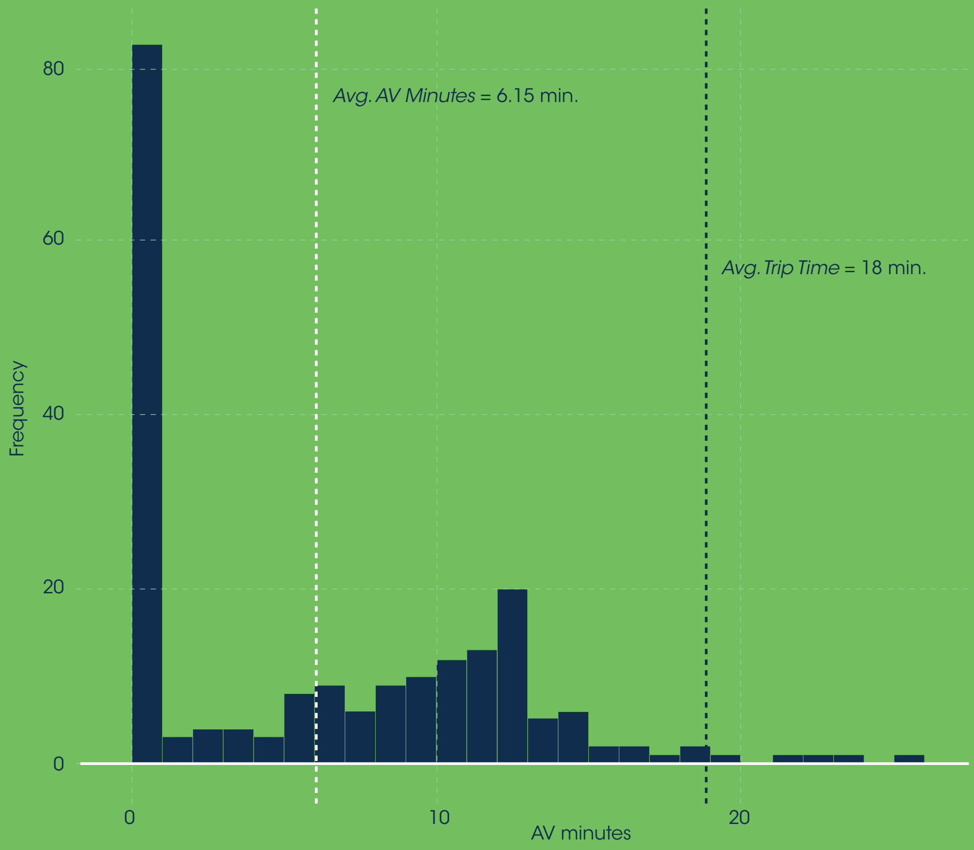
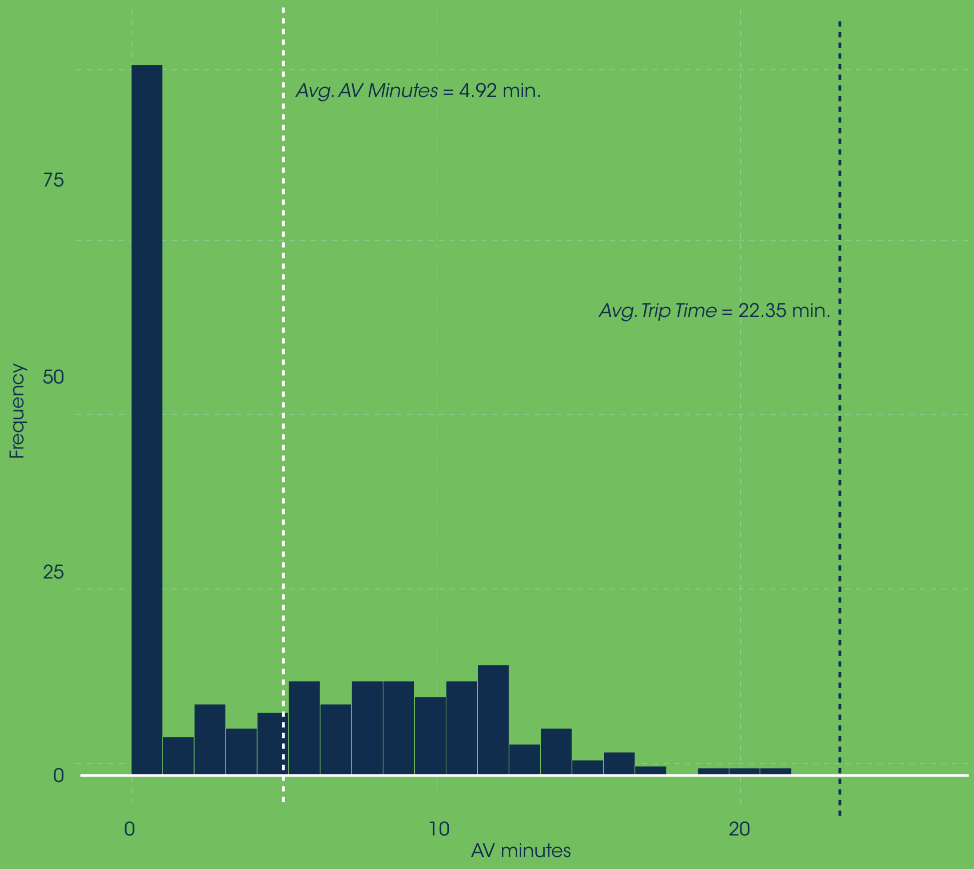


Figure 4-41. Histogram of observed minutes in AV mode per one-way (half) route observation period, from Olneyville Square to RIDOT (*N* = 217 observations, May 2019–March 2020) (*link*)



4.4. User Experiences

Data related to rider experiences were gathered via multiple methods: surveys, observational field work, and interviews. Interviews were used to gather qualitative evidence to validate survey findings and provide a deeper understanding of the service experience as well as underlying motivators and barriers to the adoption of the service.

4.4.1. General sentiment and awareness

The general sentiment of the interview participants was positive. The local riders felt a sense of pride in the City of Providence for leading the way in mobility innovation. The majority of first-time riders took the shuttle out of curiosity and interest. For example, one of the riders, a visitor from Italy, recognized the shuttle as autonomous and rode on it for several loops out of the desire to learn more about it. Another rider was in Providence for a transportation conference and learned about the Little Roady pilot project. The next day he went to the shuttle and took a full loop ride with a colleague.

Interview participants were asked how they first heard about the shuttle. Almost half of the participants mentioned that they learned about it through an information channel such as the news, an email link, magazines, or the internet. Another information channel was word of mouth that included learning about the shuttle service from the researchers that were conducting the surveys and interviews on the ground. Some riders spotted the shuttle on the streets while doing daily errands, walking, or driving on streets shared with the shuttle service. One participant stated

> *"I think it either came up in a link or maybe I just saw one on the street sometime, but I saw them going around. And I was like, I will check those out. I will see what it is. And one just happened to be very conveniently going by my house and to the train station."*

Another participant responded

> *"The shuttles looked weird enough to ask what was going on."*

Some passengers and interview participants questioned the lack of general public awareness and advertisement of the service. Many learned about the service while either passing by it or through word of mouth. The lack of awareness was largely driven by limitations placed on outreach and marketing. There was also confusion due to signage and branding. Most branding mentioned RIDOT or May Mobility but the general public associated RIPTA with public transit. Some riders, as mentioned by the researchers on the ground, were also not aware that the vehicle was an AV when they initially boarded. When the researchers handed them the survey, they seemed confused and inquired about the vehicle they were talking about.

Speed and comfort

When asked to characterize the speed of the Little Roady shuttle compared to public buses, the majority of the survey participants (37.3%) responded *about the same*. When asked how they would characterize the comfort of their experience on the Little Roady shuttle compared to public buses, the majority of the participants (51.7%) reported *extremely comfortable*. Only a few participants (5.2%) reported discomfort on varying scales.

Providing a comfortable shuttle riding experience while not compromising safety was one of the primary goals of the Little Roady shuttle service.

Interview participants were also asked what they enjoyed the most about riding the shuttle. Responses revealed that five factors contributed to the comfort and safety perception of the participants: (a) speed and motion of the shuttle, (b) design of the vehicle, (c) social experience of the shuttle, (d) affordability and access of the service, and (e) microtransit and first/last mile connectivity.

Safety

Most of the interview participants felt comfortable and safe riding the shuttle because of the low speed and smoothness during acceleration, deceleration, braking, and steering of the vehicle while making turns and changing lanes. The low speeds and smooth ride elicited a feeling of safety with many participants remarking on the gentleness of the ride and making comparisons with other electric vehicles that do not drive as smoothly.

> *"I liked the way that it made corners, that has always been an issue with electric vehicles and autonomous vehicles. They would have problems making left turns and when they sense the cars coming at them. And you know, because it was making a left turn, it glided right to a stop. And I liked the fact that it was not jerky."*

Another participant stated

> *"It was smooth, quiet, and made corners fine. I had a feeling that left hand turns might be a problem but it did not seem to be, and it pretty much sensed what it was supposed to do and pulled right into the stop."*

However, this was not always the case.

Figure 4-42. Perceptions of Little Roady service speed (*link*)

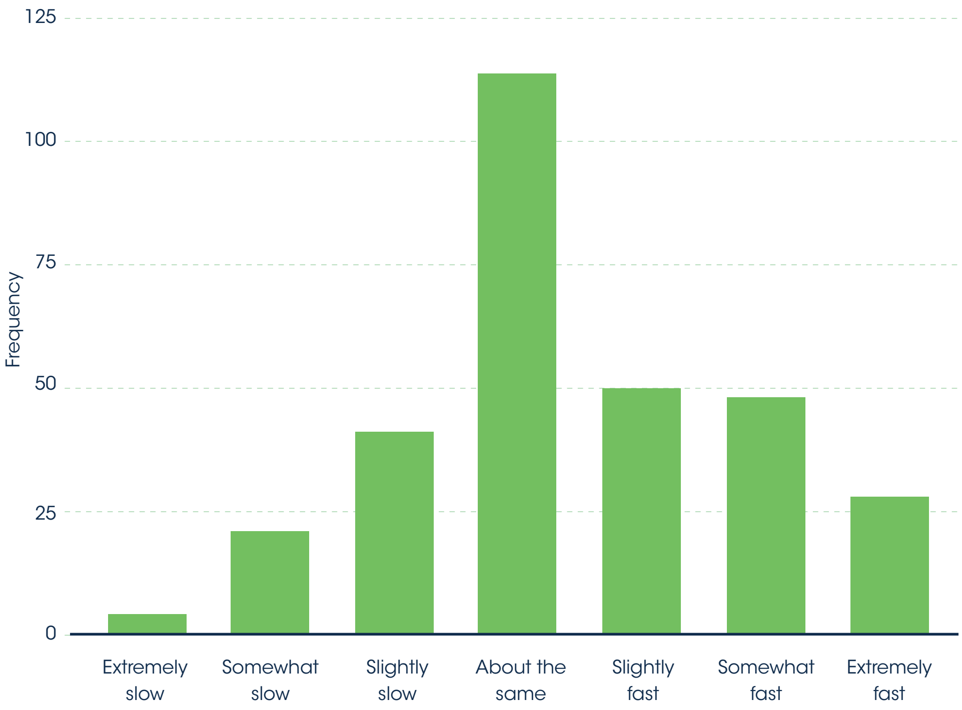
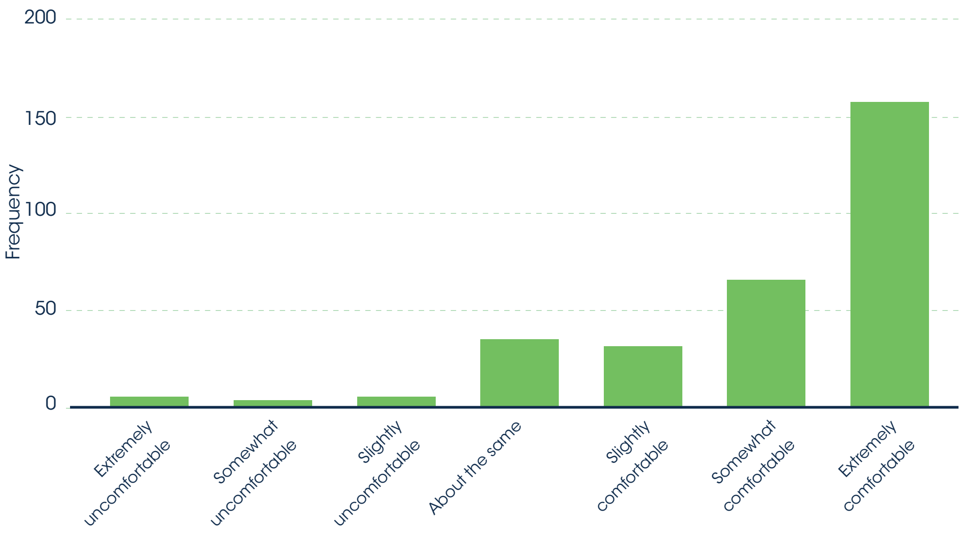


Figure 4-43. Reported user comfort of Little Roady shuttle (*link*)



During the first month of operation, there were frequent sudden stops that led to discomfort among passengers. The May Mobility engineers improvised to iron out the sudden stop issues and improve ride quality. Following these improvements, it seemed many riders could no longer discern when the vehicle was in AV mode as opposed to manual mode. The presence of fleet attendants surprised many riders and led to the realization that there are multiple levels of AV.

Design of the vehicle

The overall experience of the ride was also heavily influenced by the aesthetics of the vehicle. Design elements that led to enjoyable experience and in some cases a pleasant surprise included cleanliness of the vehicle, outside visibility through the large windows and sunroof, comfortable seating, free internet connection, and sociable interior layout of the vehicle.

Interview participants expressed enjoyment of the panoramic view and the ability to see the city "in slow motion" because of the large windows. Another remarked on the cleanliness of the units and how the shuttle "informs people's wellbeing." Many participants mentioned the services as a thing that Providence "did right" and that made them like living there. Several participants also mentioned liking the layout of the shuttle, as passengers face each other which increases their chances of interacting with each other.

Social experience of the shuttle

Given both the intimate and novel nature of the shuttle, many expressed the social nature of the experience as a positive aspect of riding. Passengers enjoyed the ability to interact with other passengers and the fleet attendant. One participant stated

"It is intimate but also the social attitude that you can get from this, such as you know you could talk to people more."

The fleet attendants also enjoyed interacting with the passengers. One of the fleet attendants stated

"I'm a people person so I like to see how I enjoy the intermingling sometimes with some of the passengers and being in Rhode Island I get a different aspect of—they're not so much the culture but I like as a people period. And basically, that's the most positive thing ever seen."

Another participant remarked on the higher probability of chance encounters.

"On the bus, it's a cold atmosphere. I get on the bus, you know the bus driver is not sociable as I've seen here. My drivers are like 'Hey welcome!' You know it is very nice. On a bus it is just quiet. You just sit down and just go about your business. Here I am talking to you now. You might see somebody that you know, or I can have this guy here working because we have free Wi-Fi. There are so many different things."

For many riders, interactions with the fleet attendants were one of the most positive aspects of the shuttle experience. They appreciated the friendliness, sociability, and knowledge about the AV technology. There were remarks made on the politeness and "extremely nice" nature of the fleet attendants. Passengers were curious about the technology, routes, service hours, and cost as it relates to Little Roady. Some frequently asked questions included topics such as:

- Route: When will the route be expanded? To Newport, Barrington, VA hospital?
- Cost: Will we have to pay for this?
- Service: What is the schedule/route? Will the hours be expanded?
- Autonomous technology: Are we in Autonomous mode? How does the autonomy work?
- Communication: Why have I only heard of this through word of mouth?
- Vehicle equipment: Is there an AC?
- Electric vehicle technology: How long does the battery last?

Affordability and access

Participants appreciated the service for filling a transportation gap, connecting east and west sides of Providence and increasing transportation equity for lower-income communities that have lower private vehicle ownership or usage and have to travel for work to downtown or use the rail on a daily basis. While cost appeared largely not to be a deciding factor, many riders were grateful for the free service that increased accessibility to areas they previously had difficulty reaching. One of the fleet attendants stated

"I get a lot of thankfulness, people that are thankful that really could actually get to a point that they probably couldn't get to before and it happens to be free."

Many participants also appreciated the 15-minute frequency of the shuttle during rush time. One of the participants pointed to the slower frequency of the bus and rail service.

"The vast majority of bus lines in Rhode Island, with the exception of the R line and a

couple of the more busy downtown lines, run every 30 minutes or every hour, which makes it really difficult to count on when exactly these services are going to come. I think every 15 minutes is a really awesome frequency. It's some of the best service in the state."

Participants that lacked the option to take a car perceived the shuttle service as a convenient and accessible option. One participant remarked

"It's so convenient. I have the option of taking the bus, but given the two of them, I'd much rather take the Little Roady thing. It feels more personal. I don't know if that would always work. But it feels more like I'm getting a ride, than I'm taking the bus. I guess that's kind of cool."

Microtransit and first/last mile connectivity

The Little Roady pilot was a form of fixed-route microtransit and provided a first/last mile solution for many residents, especially for commuters to the Boston metropolitan area. The majority of the interview participants perceived the shuttle service—much smaller than a bus—as a first/last mile public transit solution that is more energy efficient and convenient, especially for older people. It was widely understood that the smaller size allows it to go on more direct routes that RIPTA buses would not fit on. For example, one of the participants stated

"I love the size of the van because I think that way you can bring people more precisely into areas. I think there's gotta be an economy of scale where in public transportation you've got this huge bus to fill like 45, 40 seats. And if it's empty most of the day, it addresses part of the transportation needs. But maybe not in a way that something like a variety of smaller electric vehicles could do in a more efficient way and customer responsive way as well. This way, but you know, to sort of coordinate that a little bit would just be, would just be great. And I think with regard to the vehicles, for those of us who aren't ready at our ages—I'm seventy, I run, I'm in good shape—but I'm not really that excited about hopping onto a scooter. To have the autonomous vehicle would be ideal for me."

4.4.2. Concerns and barriers

Despite the considerable positive sentiment about Little Roady, there were numerous concerns expressed by the participants in relation to the shuttle service. These concerns could be broadly divided into seven categories: (a) awareness, (b) public investment and equity, (c) transit information, (d) user convenience, (e) vehicle design limitations, (f) encoded bias, and (g) environmental design and infrastructure.

Awareness

Some respondents listed lack of familiarity and awareness as an obstacle to riding Little Roady. Many riders were also concerned that other community members might perceive that the shuttle service is not for them. For example, one of the participants stated

"A potential barrier would be mental—thinking that the shuttle is not for them, seeing white, young people riding it and thinking it's for them. The area is seeing a lot of change and gentrification as well, so that could be a barrier to reaching those that need it most..."

Participants also mentioned that stop signage was not very prominent and many passengers often used the green curbs as visual cues for the stops. The green curbs were designed for AV shuttles to locate the stop. This finding indicates a need for a bolder environmental design to make discoverability of service stops easier.

Public investment, scalability, and equity

Participants lacked information on the source of funding for the service and were unsure if the autonomous shuttle service was the right choice as a government-funded project. They were also skeptical of the affordability of the service, in comparison to other transit solutions that can fill the gap, in case of an expansion. Concerns were expressed about the affordability of the service following the one-year free period. One of the participants remarked on cost being a barrier.

"Cost issue for very low-income residents ... access to public transit cards has been difficult for many people [the Little Roady shuttle] serve. It'll be important to communicate that the shuttle is free, but only for the one-year pilot duration."

Another participant pointed out that the limited seating capacity might make it difficult to keep the cost affordable.

"Certainly cost, I think. It's not huge, it doesn't seat more than four people in the back."

Transit information

A majority of the participants pointed to a lack of trip planning application that could provide information on the wait time and frequency of the shuttle at different times of the day. Some riders mentioned budgeting their time assuming it would be more frequent than it was and didn't account for the additional wait time required when the service was operating at a low frequency.

"There's not a fixed schedule so you kind of just have to hit or miss hang out there. It seems like sometimes they're clumped together and sometimes they're spread out. And the map is, I suppose the one thing I would change maybe, is some of the accuracy of the map. Because it's not really clear where they [shuttles] are in relation to the stops, bouncing through. You can't tell how close they are to the stop."

The lack of an app that could communicate the travel and wait time also didn't dispel misinformation around perceived travel time. Some participants also perceived the shuttle travel time to be longer and despite the curiosity about the shuttle service preferred their car or bike to travel to their destination, especially to go to downtown Providence. For example, one of the participants stated

"Yeah, it's nice in theory that I can take that from Rising Sun Mills to the train station. I can also take an Uber or Lyft. Or I could ride my bicycle. Or I could drive my own car if I can get there early enough to park in the garage. There's like a lot of options, you know?"

User convenience

Some participants pointed to the limited hours of operation indicating that a later stop-time (past 6:30 p.m.) is desired to accommodate returning commuters from the train, especially during the weekends and for nightlife trips. One of the fleet attendants stated

"For a lot of people in Providence, it's about doing stuff around the city and cultural events. And I think there's less of those riders but they're definitely on here. People [are] like, 'I'm going to the Waterfire Arts Center,' or 'we were doing something by the statehouse, and so we thought we'd give us a try.' And definitely in the evening when there's a lot of stuff to do in Providence. So that's why I think when people say evening, they're looking to do stuff in the city. It's not necessarily that they work at night. I think it's more like, they want to do stuff."

Vehicle design limitations

While the design of the vehicle was among the most appealing factors for the rider, some participants pointed out certain limitations to the design as they relate to (a) accessibility of the vehicle, (b) size of the vehicle, and (c) interior layout of the vehicle. The vehicle was not ADA compliant and lacked a booster seat for children. There was a Veterans Affairs hospital in close proximity to the route of the shuttle that could lead to a demand for wheelchair access. This could have prevented some passengers from using the shuttle service. For example, fleet attendant stated

"The only customers that don't get on it's because they don't have a car seat for their child. Or because of disabilities."

Another participant expressed

"I also have a four-year-old and I know that for a younger child to be able to ride a car seat is required. Trying to get on a shuttle with a car seat, buckle it in, and then once you get off having to carry that car seat

around it would prevent me from riding that with her. So if there was an option for a fold-down car seat that's built into the seat. That would be a huge bonus for me."

The fleet attendants also pointed to the demand for a booster seat.

"I wish we had a booster seat. At least one, or a car seat. At least one. Because there'll be some mothers you know traveling with infants or kids that really would love to jump on the shuttle and help them out, but they're not going to walk around with a booster seat all day or a car seat all day. So if that can be somewhat included into the shuttle that'll be a great thing."

A few participants reported difficulty closing the door from behind because the seatbelt would get struck. Some discomfort was also reported on hot days due to lack of air conditioning. Passengers frequently asked fleet attendants if the vehicle had air conditioning. The feedback was reported back and air conditioning was made available in the vehicles.

A couple participants noticed that the small size of the vehicle could prevent a family or large group of riders from using the service. One of the participants said, "I could see if a family might want to try and use it and have that be a bit of a tight fit." Another participant remarked on limited space for cargo, pointing to the lack of alternative use for the vehicle and the inability to carry riders' luggage.

Encoded bias

A few interview participants were concerned about regulation of autonomous cars with utilitarian ethics that will raise ethical dilemmas. The autonomous vehicles would need a coded bias to be able to make a decision when faced with a possibility of a fatal incident. Some participants saw the government playing an active role in resolving these conflicts. Examples of interview responses to this item are included in the attitudes and perceptions section of this report.

Environmental design and infrastructure

Some interview participants provided feedback on the environmental design of the stops and infrastructural plan of the service. Riders remarked on the inconsistency in the design of the stops, as some stops were using existing RIPTA stop locations and as such had more lighting, seating, and roof coverage than stops unique to the shuttle. A few participants pointed out the lack of signage on stops.

"It's cool that they have unique stops to let you know this isn't just a normal bus stop. But I think it would also be helpful if there were a RIPTA sign on the stop. The stop markers as well because I've been in it sometimes when people get in the vehicle and they're not really sure what it is. And I think you can tell them, okay, like this is actually a bus. You can rely on this like bus service. Although of course signage would be great."

Because of hours of operation,

lighting was pointed out to be less of an issue but would be a desired element if service was to be expanded to late hours.

Comparison with public transit

Interview participants often compared Little Roady to services provided by RIPTA, indicating that riders and respondents interpreted the shuttle as a new public transit option. While bus and shuttle services are not directly comparable, given differences in size and scale of the services, the comparison provided some insight into factors that facilitate faster adoption of a new transit technology. For example, interview participants revealed that there is a stigma attached to public transit.

The buses were perceived as less comfortable because of overcrowding and there was a general perception that they were less well maintained and not as clean as the Little Roady shuttles. Participants also felt conventional bus drivers lacked the ability to interact with the passengers because of manual driving responsibilities.

It should be noted that this perspective contrasted with self-reported perceptions among RIPTA drivers related to their job activities. In interviews with our researchers, RIPTA drivers stated that their job activities extended beyond driving and included actively interacting with and helping passengers.

RIPTA bus service was seen as affordable and people applauded their efforts, but it was not as convenient as private transportation options because passengers had to make transfers at Kennedy Plaza. Most of the passengers from the Little Roady service area did not have direct routes through RIPTA bus service, increasing their trip time in comparison to a car or taxi. One of the participants stated

> *"It's not always a straight A to B line for a lot of people on their trips. You have to make that transfer at Kennedy Plaza. The pros is that you can get pretty much anywhere ... but the con is it takes longer. I know that they work really hard there. Great team at RIPTA."*

This underscores the transportation gap that the Little Roady shuttle service was fulfilling and a need for an alternative transit option in the Woonasquatucket River Corridor.

Fleet attendant experiences

The research team also conducted interviews with the fleet attendants to get an insight into their experience while driving the autonomous shuttle. Overall, fleet attendants reported positive experiences working for May Mobility. Several fleet attendants reported fair treatment on behalf of May Mobility and felt that the company cared for them, citing that they were paid well and given breaks when needed. For example, one of the fleet attendants remarked that they had an easy process to change their shifts if they desired, and were welcomed to take a coffee break at any time they felt tired.

The job was steady and secure, at least until May Mobility suspended service citing concerns with COVID-19 on March 13, 2020. Some fleet attendants also mentioned that they perceived the job to be meaningful where they had the opportunity to address a real need in the community, especially closing the last mile gap for senior populations and veterans who, according to the fleet attendants, were frequent riders. The fleet attendants enjoyed the social nature of the team and frequently had group outings. They were provided with an app called Mumble for scheduling and communication with other fleet attendants during their shifts. Many fleet attendants had a service industry background and liked the social aspect of the shuttle. They also often played the role of a crisis manager, particularly in relation to addressing safety issues on the shuttles.

Some of the fleet attendants expressed the need for more garage space within the base of operations. They perceived the garage to be small for 12 vehicles and the array of technical tools, and documents and files associated with running the pilot. They also mentioned that on hot days or during the summer, the garage overheated overnight due to the charging needs of the shuttles. At times, they reported that electric vehicle service equipment was not adequate to charge a fleet of 12 vehicles at one time. One fleet attendant stated

> *"It gets pretty cluttered in here [base] fast. I think it's just because we have 12 shuttles. Plus we have to put everything that we need, the technicians stuff, and like the office stuff."*

The road side units (RSUs), generally used as a self-organized network solution for increasing the connectivity of the shuttles, did not have the technology to communicate with the shuttles directly and only served as a recording camera communicating with the base. See section 5.3.1. for more information related to RSUs.

One of the main pain points for fleet attendants was associated with the coordination required to accommodate fleet attendant shifts within vehicle battery spans. Fleet attendants would have to transfer to another vehicle every so often at the depot because of the battery or fleet attendant shift changes. If other passengers were in the shuttle at these times, fleet attendants sometimes waited until they dropped off passengers and coordinated on Mumble to try to alleviate these issues.

Despite RIDOT's requests and requirements, May Mobility did not consider *time in AV* as a success metric at launch, but at some point they started tracking time in AV and ranked the fleet attendants to incentivize and motivate them to operate in autonomous mode. As noted by one of the May Mobility supervisors, many fleet attendants initially moved through certain parts of the route in manual mode because it was faster to do so. The ranking incentivized the fleet attendants to let the vehicle remain in autonomous mode. ●

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5.0

Discussion: Governance and Management

Iterative analysis of data gathered in service of the established research questions revealed notable findings related to the governance, management, and operations of the Little Roady pilot shuttle. The following discussion is based on a triangulated analysis of project data, including a series of interviews conducted with various stakeholders and project partners both at project initiation and completion. These lessons are presented through the lens of a government partner as it relates to developing and implementing AV transit programs of this nature.

5.1. Partner Engagement

The Little Roady pilot not only acted as a testing ground for the AV shuttle pilot itself, but also for the partnerships necessary for planning, operating, and regulating an AV shuttle. Little Roady was born out of the Transportation in Innovation Partnership (TRIP), a platform created for Rhode Island to explore new innovations in transportation technology and engage in simultaneous education, inquiry, and dialogue among partners at the State and local levels, and with experts within the private and public sectors.

Partnership formation was initiated at a TRIP Expo for stakeholders to participate in panels, conversations, and tours of potential project locations to weigh the pros and cons. The intention of the partnership was to have regular participation and to advance the research and the conversation. Further, deployment of the AV shuttle pilot on City-owned public roads in Providence would not have been possible without City approval since RIDOT does not have domain over such roadways nor the traffic signals along such routes. Involved partners in TRIP and the Little Roady deployment included: RIPTA, the City of Providence (City of Providence Chief of Staff, Planning Department, and Department of Public Works), the Rhode Island Division of Motor Vehicles, the Rhode Island Division of Public Utilities and Carriers, key Rhode Island and Providence safety officials, the Quonset Development Corporation, and the Federal Highway Administration.

Launching the driverless shuttle service in an urban environment versus a closed campus called for a complex set of partners. Conversations with various official sources revealed that early-stage engagement helped to shape the pilot to more meaningfully advance the local, regional, and national conversation. Cross-partner dialogue helped identify topical areas of relevance and components to include grounded in transportation issues, coalesce partners with shared interests in exploring AVs, and ensure the partnership was structured to learn from the deployment.

However, ongoing engagement proved more challenging due to both internal and external forces. Capacity for project management—from RFP formulation to vendor management—was limited and led to fewer opportunities for TRIP member engagement. Additionally, a lack of a formal, structured TRIP process to set expectations, clarify roles, and elicit commitments early on contributed to a sense of “stepping on toes” among partners.

Larger partner convenings organized to share findings at the midpoint were not as successful as one-on-one conversations held later in the pilot cycle to elicit feedback on and interpret the data, as well as surface opportunities and considerations relevant to each organization for a potential second phase of the Little Roady pilot, whether related to a need, impacts to stakeholders, potential for innovation, or policy impacts. ●

Discussion

5.2. Vendor Procurement

A major driver for RIDOT to initiate the Little Roady AV shuttle pilot was to gain first-hand, real-world experience to inform regulators and cities when and how to be ready for AV technologies by understanding how ready the industry really is. To that end, Little Roady was solicited as a public-private partnership under a best-value procurement model that also incorporated a separate and independent research component (this report). According to sources involved in the RFP process, a public-private partnership approach was determined to be the best fit as it seemed there were many companies looking for opportunities to deploy their technologies.

Ultimately, a balance was struck between what was learned through the RFI, partner interests, and research goals. Factors considered towards the creation of the RFP included: (a) willingness of partners to engage; (b) site considerations; (c) established associations; (d) opportunities for optimizing outcomes of the pilot such as ridership, trialing on public roads versus private; and (e) potential for ample learning. Consideration was also given to the structure of the RFP to provide clear goals while leaving room for the private partner to propose what they could provide and offer.

May Mobility was ultimately awarded the contract based on the high score garnered through their response on both the technical and cost components, resulting in a best-value award that far exceeded what other respondents were offering and promised to push the envelope. Some of the main criteria that contributed to their selection included cost, length of route, ability to serve a mobility need, and ability to provide a turn-key automated service.

However, with few examples of public-private partnerships of this nature to compare to, the procurement process had a learning curve, and negotiations took longer than anticipated, as many expectations stated in the RFP required negotiation.[1] Most notably, while the RFP listed data reporting requirements, some requirements were ultimately relaxed during contract negotiations. With reduced data requirements and no clear specifications of data or performance reporting requirements, the project team's ability to learn from the pilot was hindered. Despite the RFP requiring the service to meet or exceed Society of Automotive Engineers' (SAE) level 3 of automation, there would have been no way to determine whether this threshold was met because no raw autonomy data was shared. Data governance and sharing is further detailed in section 4.5.4.

As another example, the RFP also required the service to meet all federal safety and Americans with Disabilities Act (ADA) standards, yet in practice, none of the original vehicles were ADA accessible. Noncompliance resulted in the withholding and loss of federal grant funding during the project earmarked for further examining Little Roady as a microtransit solution. Eventually, this was partially addressed by May Mobility through the provision of an on-call wheelchair accessible vehicle that became available for requests in mid-September of 2019 (May Mobility, 2019c). The fact that a special vehicle was required to meet this requirement, as opposed to the standard May Mobility shuttle, represents a barrier to accessibility that remained in place throughout the pilot. ●

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[1] Subsequent to finalizing the contract with May Mobility, the U.S. Department of Transportation introduced a grant opportunity that could have supported additional research extending form the pilot. However, linked to the grant was a new and more extensive data sharing requirement. RIDOT ultimately decided not to pursue the grant given the challenges experienced negotiating data sharing practices with May Mobility.

5.3. Operational and Technological Readiness

At the time of its launch, Little Roady was framed as the longest active public AV transit route in the world and the first AV and EV public transit option available in Rhode Island (Bloomberg Aspen Initiative on Cities and Autonomous Vehicles, 2019). Operating in real-life, unprotected urban conditions along a 5.3-mile fixed route was novel for an AV pilot. In launching the RFI/RFP process, there was an expectation that operationalizing an autonomous public shuttle program of this magnitude would be a challenge and learning curve for all involved.

Challenges encountered during the pilot deployment revealed a lack of operational and technological readiness for this context but also underscored the importance of collaboration, partnership, and role definitions between public and private sectors. This section is intended to provide a description of the learning curve experienced by the involved parties.

5.3.1. Technology and infrastructure

At the onset, obstacles encountered in laying down the infrastructure—real estate, staffing, training—and troubleshooting compromised May Mobility's ability to focus on ongoing service success. As described in interviews with May Mobility and RIDOT representatives, May Mobility encountered significant technical and operational challenges at the beginning of the pilot and through the summer of 2019, resulting in service reliability issues. Figure 4-30 illustrates that the months of July and August 2019 were the lowest performing in terms of SLA compliance, with the lowest average number of vehicles on the road and longest headways.

While May Mobility had previously dealt with cold weather during the winter months in other pilots, high heat was a new condition, which resulted in vehicle and cooling breakdowns and created vehicle availability issues. In their August 2019 monthly report, May Mobility (2019a) stated that they "continued to face challenges with vehicle reliability" (p. 15) with many instances of reduced SLA compliance "due to vehicle maintenance and charging needs" (pp. 17–19). Many of the vehicles were operating in full manual mode due to broken sensors and supply chain issues experienced during this time, preventing the sourcing of replacement hardware.

Electrical power available at the warehouse proved insufficient to recharge the 12 EVs overnight. Insufficient connection speeds at the warehouse also created issues in downloading data and semantic maps overnight, a need driven by the high sensitivity of the semantic maps, which require frequent adjustments to enable AV performance, particularly provided the complex nature of the shuttle route. For example, an adjustment may be required if the LiDAR system interprets thick grass as a solid object which activates the system's short-range emergency stop.

Adjustments to the semantic maps required understanding disengagements within the context of the shuttles' ODD. It involved reviewing the autonomy rates, correcting for deviations or outliers by vehicle or attendant, identifying peaks, troughs, and hotspots for autonomy, and triangulating with conversations with fleet attendants to provide additional context. Throughout the course of the pilot, the need for constant updates to the semantic maps also necessitated continuous manual adjustments to the software, which affected AV performance. Complications related to novel infrastructure deployment also created hiccups, such as the delayed implementation of roadside units (RSUs). May Mobility preferred hardwired RSUs, instead of battery-run RSUs to avoid the need for frequent replacement of the batteries, an effort that required permitting for installation on utility poles and coordination with different utilities and public entities. RIDOT's involvement in obtaining the necessary permitting was instrumental to moving this effort along.

In Little Roady's case, the RSUs were described as effectively mounted cameras that conveyed captured images to the vehicles. A preliminary report from May Mobility included an assessment of potential mounting locations for RSUs including light poles, traffic signals, pedestrian crossing poles, speed camera poles, and National Grid/Verizon poles (May Mobility, 2019a). A final map of their locations was not provided to the research team. Moreover, the RSU cameras were described by participants as inconsistent and unreliable depending on weather conditions, with issues ranging from glare on sunny days to visual interference on rainy and windy days. The utility of this particular RSU deployment is unverified as it has not been established whether the shuttles had the necessary programming to receive or respond to information transmitted by the RSUs.

Fleet attendant interviews seemed to indicate that RSU data was interpreted by fleet attendants, not the vehicles, to adjust driving behavior. For the RSUs to have been effective for an AV application, a more robust rollout of dedicated short range communications (DSRC) infrastructure and encoding into the vehicles themselves was necessary, such as intelligent signals. Stakeholder engagement in January 2020 surfaced implementation of DSRC technology and infrastructure as a key opportunity for a continued Little Roady pilot. But with technological advances in this arena, such as C-V2X hinging on broader 5G deployment, deployment of DSRC remains in a holding pattern. Given the two-sided nature of such infrastructure deployment, May Mobility indicated a willingness to invest in DSRC, but signaled this would be only after a clear indication of an intention to invest by RIDOT and its stakeholders.[1]

Little Roady shuttles' ability to complete unprotected left turns in AV mode also remained a challenge throughout. As noted, the largest observed cause for autonomous disengagements was unprotected left turns at 29.6% of incidents notated by the field surveyors (Figure 4-39). As drivers often behave based on non-verbal cues from other drivers that indicate when it is safe, unprotected left turns are one of the most challenging maneuvers for AVs. As more training data becomes available, the easier it becomes to predict other driver behavior, making the maneuver easier.

In shifting from May Mobility's pilots in the Midwest, it also became evident that adjustments needed to be made to account for local driving behaviors in Providence, but not only from the technology side. According to May Mobility's July 2019 report, to underscore safe driving following several incidents per RIDOT's recommendation, May Mobility's fleet attendant trainer provided additional defensive driving training for the Providence team, including the site manager, site supervisors, and fleet attendants to raise awareness of their driving tendencies, encouraged safe driving, and taught how to compensate for uncontrollable situations. The course was modeled from the National Safety Council Defensive Driving Course.

Despite challenges in AV technology performance and infrastructure, improvements in autonomy utilization along the route were observed in October 2019. According to May Mobility's October report, contributing factors to the improved performance included

> *"...concerted efforts to continue to improve fleet attendants' trust in the May Mobility autonomy system, improvements to the semantic maps that underpin on-route behaviors, improvements to the global May Mobility behavioral and perception systems, and stabilization of roadway construction throughout the Little Roady circuit." (May Mobility, 2019d, p. 41)*

Such reporting underscores the role of fleet attendant trust and behavior in AV performance.

5.3.2. Partner coordination

In the midst of the early operational and technical challenges, a lack of transparency with respect to reporting, documentation, and communications prevented RIDOT from being able to assist with troubleshooting. A testing

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[1] Cellular Vehicle to Everything (C-V2X) supports continuous vehicle to vehicle (V2V), vehicle to infrastructure (V2I), and V2P (vehicle to pedestrian) communications but relies on 5G network deployment—nearly 20 times faster speeds and low latency of devices—to support the instantaneous data processing needed for real-time communication between AVs and fellow road occupants.

plan or protocol was never shared with RIDOT, and despite early efforts to align on a reporting template, the reporting was not streamlined until September.

Although May Mobility cited frequent communication and collaboration, RIDOT staff were not permitted to visit the May Mobility office unannounced, and particularly in the early months, operational issues often were not communicated and resolved to the satisfaction of RIDOT. Research and data collection from May Mobility's end took a back seat to the operational and service issues.

The lack of responsiveness to RIDOT by May Mobility on-site staff introduced significant enough roadblocks that May Mobility implemented staffing changes following the first months of operation. Following these changes, partner communication improved, which supported more streamlined operations leading into the fall months. The continued presence of a May Mobility Customer Success liaison was noted to be instrumental in advocating on RIDOT's behalf to implement changes. May Mobility representatives, moreover, indicated that increasing involvement of May Mobility's headquarters team, refining fleet attendant training, and prioritizing reduced headways as a primary performance metric helped shift focus and improve operations.

5.3.3. Workforce and staffing: Fleet attendant management

The Little Roady service created 25 jobs in Providence, operating with 20 fleet attendants contracted through a temporary work agency, and five key staff members hired and managed by May Mobility for the duration of the pilot. There were three roles on-site, a site manager responsible for overall coordination, a supervisor responsible for day-to-day fleet attendant management, and a technician to conduct maintenance. At any given time, Little Roady had three to six fleet attendants on the road (one per vehicle) with two fleet attendants on break. The day was broken into three shifts of 2.5 hours each.

The official responsibilities of fleet attendants included: (a) operating and shifting the vehicle from AV to manual modes at key moments, and operating the shuttle fully in manual mode; (b) enforcing safety measures such as reminding people to wear seatbelts; and (c) engaging in the stewardship of the technology and service including responding to questions asked by the passengers about the route, AV technology, the electric vehicles, and other related topics. In practice, the fleet attendant role also promoted word of mouth marketing by encouraging pedestrians to utilize the service, and also by ensuring safety on the vehicles in case of unruly passengers.

Fleet attendants were hired with communication skills as a key criterion and trained to provide an informative, friendly, and safe environment to riders, reinforced through rider interviews that cited fleet attendant friendliness as a key factor contributing to overall trip comfort, experience, and sense of safety. Another consideration was hiring fleet attendants who could speak Spanish.

Interviews conducted with the May Mobility staff and supervisors revealed that in addition to hiring criteria, fleet attendant training played a key role in the autonomy performance and overall safety. Training not just at the onset but on an ongoing basis, informed by intensive monitoring by site managers, helped the fleet attendants understand and feel comfortable with the technology.

Fleet attendant training included initial onboarding, including three weeks of classroom and in-vehicle sessions with trainers and two weeks of on-route testing during a mock deployment, as well as ongoing training on an as-needed basis. Adjustments were made to the training to address new needs that arose once the shuttle service began, which was reflected in the higher and immediate comfort level of the fleet attendants that were hired later than those who were initially onboarded. The higher comfort level could also have been due to improved hiring criteria. As noted by one May Mobility representative, "you don't need to be a robotics engineer to be comfortable with this technology, but it does take training."

It should be noted that there was a high initial turnover rate among the fleet attendants. Some fleet attendants also did not adhere to the random toxicology and drug tests requirements and hence were needed to be replaced. May Mobility adjusted their hiring criteria to ensure that fleet attendants affirmed the toxicology test requirement.

Reflection interviews also revealed a perception that due to the high frequency of disengagements and the need to operate the passenger-carrying vehicle in manual mode, additional training could have helped alleviate some of the incidents and safety issues that arose over the course of the pilot.

5.3.4. Accessibility

The May Mobility shuttles utilized on the Little Roady pilot project were not ADA compliant, nor were they wheelchair accessible for the first several months of operation. To ensure that the overall service was accessible, May Mobility entered into an agreement with RIPTA whereby RIPTA would provide paratransit service in the corridor to riders needing ADA service. However, May Mobility took efforts to produce, pilot, and test a wheelchair accessible vehicle, which became available to the public on the Little Roady route as of September 8, 2019.

According to May Mobility, the service could be requested by riders via a phone number, email to customer support, or by talking to a fleet attendant. Prior to deployment, on-route testing was done by May Mobility and RIDOT with the wheelchair accessible vehicle (WAV) on September 5, 2019 (May Mobility, 2019c). However, no requests for the WAV were received through the duration of the May Mobility operated pilot. This may be due to the lack of marketing and advertising surrounding the service. Stakeholder reflections held in January 2020 surfaced that advertisement about the wheelchair accessible vehicle was an area for improvement.

According to a marketing plan issued by May Mobility in March 2020, wheelchair accessible shuttle postcards were created early in the month but this coincided with the onset of the COVID-19 pandemic.

Aside from limitations related to ADA compliance, May Mobility shuttles were not outfitted with storage space for large luggage, carts, strollers, or bicycles, which posed challenges for riders with cargo. Additionally, the shuttles did not have car seats, which prevented small children from using the service unless the guardian had an approved car seat with them.

5.3.5. Operational cost

Throughout the duration of the pilot, the Little Roady AV shuttle pilot was offered as a free service to riders. While the total value of May Mobility's contract with RIDOT was $800,000, the true cost of the service was not disclosed by May Mobility, which raises concerns about the long-term financial viability of the service, including whether the service could remain free indefinitely and if not, at what eventual cost to riders.

The Little Roady service filled a transit gap between the historically low-income neighborhood of

Olneyville and the downtown central business district, making ride cost a particularly salient access issue for many residents along the corridor.

> *"[It is a] cost issue for very low-income residents ... access to public transit cards has been difficult for many people [the Little Roady Shuttle service] serves."*

Given that the RIPTA service cost per hour of operation was $82.72, it can be assumed that the true operational cost exceeded the lump sum of the contract. (Based on the $800,000 contract and assuming 365 days of operation with 12 hours of operation per day, the May Mobility service cost per hour would be $182.65, but as stated above, the actual hourly service cost to May Mobility is unknown.) The financial sustainability of the model and the trade-offs that riders might be taking, or that future riders may need to take, are still unclear.

5.3.6. Incident reporting and management

Initially, operational incidents were reported informally by May Mobility to RIDOT. However, the process became more standardized throughout the pilot, in the form of a summary of incidents included in monthly reports from May Mobility, as well a summary incident log generated in January 2020 (May Mobility, 2020a). Reported incident variables included (as applicable): date, time, description, and relevant staff, and police report number, among other variables. However, descriptions of what occurred with each incident, and why, were limited to engineering assessments and images. Missing from incident reporting is more granular data, originally called for in the RFP (Rhode Island Department of Transportation, 2018).

> *"Vehicle Safety Record as indicated by number and frequency of incidents and number of required Operator interventions including number of automatic and manual disengagements and time for Operator to assume control. For the purpose of this project, RIDOT is utilizing California's DMV's definition which defines disengagement as "a deactivation of the autonomous mode when a failure of the autonomous technology is detected or when the safe operation of the vehicle requires that the autonomous vehicle test driver disengage the autonomous mode and take immediate manual control of the vehicle." (Rhode Island Department of Transportation, 2018, p. 25)*

> *"Summary of all disengagements by cause, both as a result of the autonomous technology and of the Operator taking control when required for safe operation. The report must include Miles Driven in Autonomous Mode, Total Miles Driven, Number of Automatic Disengagements, Number of Manual Disengagements, Location of Disengagement, Time for Operator to assume control and Number of disengagements by cause including, weather conditions, road surface conditions, construction, emergencies, accidents or collisions, unwanted maneuver, perception discrepancy, software discrepancy, hardware discrepancy, incorrect behavior prediction, or other road users behaving recklessly." (Rhode Island Department of Transportation, 2018, p. 25)*

5.3.7. May Mobility-initiated COVID-19 service suspension

On March 12, 2020, RIDOT received notice from May Mobility that they intended to suspend service indefinitely in response to shelter-in-place orders and other factors associated with the emerging COVID-19 pandemic, a decision that RIDOT officials frame as unilateral on the part of May Mobility. In what turned out to be May Mobility's final monthly report, they stated

> *"Due to the unprecedented COVID-19 situation, May Mobility suspended service starting March 14th. A statement was delivered to RIDOT, which can also be found on the May Mobility website. May Mobility is looking forward to getting through this unforeseen time and returning to service." (May Mobility, 2020b, p. 2)*

In limited direct communications with RIDOT, May Mobility representatives expressed general concerns about the COVID-19 pandemic, the size of the Little Roady vehicles, and the proximity of passengers to each other, but their rationale for permanent suspension of service was not communicated to, or negotiated with, RIDOT.

It was determined internally by RIDOT that May Mobility's departure from the pilot was not sufficient justification to prematurely end the public shuttle service. In its place, RIDOT and RIPTA partnered to fill the resulting service gap via a RIPTA shuttle service that operated on the same route and at the same frequency as the May Mobility AV shuttle. After two days without service, the RIPTA shuttle began in place of the May Mobility shuttle on March 16 and continued through June 30. ●


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5.4. Data Governance: Data Sharing and Reporting

RIDOT sought to ensure comprehensive data reporting as part of the Little Roady AV pilot for numerous reasons. Robust access to relevant data is of utmost importance for academic research endeavors like the TRIP Mobility Challenge that seek to understand the impacts and opportunities presented by new technologies and services like autonomous vehicles.

Likewise, when services are delivered through public-private partnerships (PPPs), data sharing can build trust, foster real-time coordination, and ultimately help ensure that contractors acting on behalf of state agencies are held accountable to the public interests for which a PPP has been formed.

Additionally, whenever a new service or approach like Little Roady's autonomous shuttle service is piloted for the purpose of performance and safety evaluation, operational and performance data is crucial for state officials to conduct that evaluation empirically and to build trust in their conclusions with members of the public.

For all of these reasons, the Transportation Innovation Partnership (TRIP) included information-gathering and sharing as a core principle of their work from the beginning, and stated that "data-sharing agreements should be framed to bring benefits to both public sector agencies and private companies while protecting the privacy of individual users" (p. 2). Accordingly, RIDOT and TRIP defined performance measurement and monitoring as "critical elements of the TRIP Mobility Challenge" (p. 24) in an Autonomous Vehicle Mobility Challenge RFP issued in May of 2018 seeking private sector partners to operate an autonomous vehicle passenger service as part of a research-focused pilot (Rhode Island Department of Transportation, 2018). The RFP continued

> *"Vendors must maintain an active database with operating statistics, disengagements, interventions, ridership, etc., from which any of the required performance measures can be calculated and required reports prepared. RIDOT must have direct access to the raw data in the database in digital format." (Rhode Island Department of Transportation, 2018, p. 24)*

While primarily focused on testing AV microtransit shuttle service operation, the Little Roady pilot also offered an opportunity for RIDOT to pilot and learn from its approach to data sharing and reporting from a private AV operator, May Mobility, in the context of a research-focused public-private partnership.

Despite outlining an ambitious vision for robust data sharing to drive research, performance evaluation, policy and planning, as referred to in the request for proposals, May Mobility held reservations about sharing all requested data due to the proprietary nature of the data, privacy concerns, lack of contextualization, and lack of specific use cases for data cleaning and filtering.

Ultimately, diverging interests between RIDOT and May Mobility (Figure 5-1) led to a more limited set of data and reporting. This section recounts the nature of the data that was ultimately shared from May Mobility to RIDOT and the TRIP research team.

Figure 5-1. Data sharing perspectives and opportunities

The diagram below illustrates differences in perspective related to data sharing and ownership as expressed by RIDOT and May Mobility representatives, as well as potential opportunities to bridge the gaps between them.

"We can't share AV data because..."

- *It contains proprietary business info or sensitive information.*
- *Without additional context such as the operational design domain (ODD) disengagements can be misunderstood, or even lead to perverse incentives for operators when used as a performance metric.*
- *Raw data is messy and hard to understand; We will need to clean/filter raw data depending on the use case or research question to make it understandable to those outside the business.*

"We need access to AV data because..."

- *Program managers need data to oversee operations, determine service plan compliance, and evaluate pilot performance.*
- *Academic researchers need granular data ... to understand the state of emergent technology and the readiness of government policy, planning, and infrastructure.*
- *Policymakers need relevant performance and safety data to properly regulate emerging industries and services."*
- *Planners need data to envision new right of way infrastructure to accommodate AV tech.*

Data sharing and ownership opportunities

- Require robust sharing of metadata and an inventory of data systems and sources collected and/or maintained by AV operators.
- Map data sources to clearly defined research questions and use cases.
- Align early and explicitly on AV disengagement data reporting requirements, including agreeing on a level of AV disengagement granularity.
- Establish data infrastructure and team data competencies to securely ingest, host, permission, and analyze large AV datasets.
- Utilize existing data standards such as GTFS to make service discoverable to riders via mobility apps as soon as the service launches.
- Push for open standards and interoperability.

5.4.1. Data warehouse, APIs, and monthly reports: How data was shared

The Little Roady Research team's scope included the deployment and configuration of a data warehouse to ingest, host, and analyze relevant data from May Mobility's operation of AV microtransit services. Later, when the Rhode Island Public Transit Authority (RIPTA) took over microtransit shuttle operations on the Little Roady route on March 15, 2020, this data warehouse also served to ingest, host, and analyze data from RIPTA. This section is primarily concerned with data sharing from May Mobility.

Throughout the pilot of autonomous shuttle services, certain operational data—primarily concerning shuttle ridership, shuttle locations, energy consumption, service hours, and distances traveled (May Mobility, n.d.)—was shared by May Mobility and ingested and stored on behalf of RIDOT by the research team. May Mobility shared this data in real-time via an Application Programming Interface (API).

In addition to this real-time data, May Mobility also shared certain metrics and figures on a monthly basis via PDF reports emailed to RIDOT and supplemented with Microsoft Excel spreadsheets containing limited data, primarily on time of service operation, ridership, and distance traveled.

Data sharing and reporting successes

The real-time API provided benefits to RIDOT during the course of the pilot:

- The TRIP research team was able to configure an operations dashboard for RIDOT staff, allowing real-time access to metrics powered by the May Mobility API, including:
  - passengers boarding and alighting by stop, as well as passengers left waiting by stop;
  - passenger-trips by hour and by day;
  - distance traveled;
  - EV battery levels/energy consumption;
  - accurate route path and station stop locations; and
  - real-time vehicle locations.
- Using the machine-readable data received via API, the RIDOT team was able to generate and monitor key agreed upon service plan metrics and other performance measures, configured to update dynamically and automatically as new data was received, including:
  - number of vehicles deployed during peak and off-peak hours of operation,
  - headways,
  - hours of service operation, and
  - ridership figures and trends.
- The data warehouse provided a user interface for querying historical data, allowing RIDOT staff to easily answer questions such as: "*How many passengers rode the shuttle service on August 12, 2019 from 3 to 4 p.m.?*" (answer: 17 passengers), or "*What was the average systemwide headway on January 30th, 2020?*" (answer: 7.5 minutes).
- The data management infrastructure set up to ingest May APIs also supported the transformation of May data into a General Transit Feed Specification (GTFS)-compliant schedule feed, allowing for the inclusion of the pilot microtransit shuttle route on trip planning applications Google Maps and Transit App.
- Finally, having a shared source of truth between vendor and state agency supported operational coordination. For example, RIDOT was able to observe actual ridership trends in the data, prompting conversations about whether "peak" service hours were properly calibrated to align with rider demand and whether weekend hours of operations should be shifted to later in the day.

These successes point to the possibility of the use of real-time APIs in conjunction with dashboard platforms to facilitate responsive, operational level decisions such as adjusting service characteristics to better meet demand. Evidence of this potential would not have been possible without RIDOT's proactive deployment of a data warehouse for collecting and structuring machine-readable data and was supported further by May Mobility's provision of a documented API to support real-time information sharing.

Data sharing and reporting limitations and challenges

Along with these successes, the Little Roady pilot also encountered data sharing challenges and limitations:

- Much of the data originally requested by RIDOT in the RFP was not included in the final vendor contract or in a separate data sharing agreement. As a result, some requested data, including

autonomy disengagement data, was not shared in a machine-readable format, suitable to analysis, or was not shared at all (Table 5-1).
    - **AV disengagements:** No data provided on number, type, or cause of disengagement, only a static aggregate heatmap that showed relative frequency of disengagements along the shuttle route via a color gradient
    - **Incidents/crashes:** Data provided only via PDF
    - **Operational cost (per rider/per hour):** Data provided only via PDF, and incomplete
    - **Miles driven in autonomous mode versus miles driven in manual mode:** Data not provided
    - **Battery performance:** Data provided not of sufficient quality to derive relevant metrics
- Some charts, graphs, and metrics provided via monthly report PDFs did not include clear documentation of the methodology by which they were produced, or did not match data provided via the real-time API. For example, headways produced via API data did not always match headways reported in monthly PDFs.
- Some service plan requirements, such as how many vehicles were "deployed" at a given time lacked clear definitions or were otherwise not measurable directly in the data, limiting RIDOT's ability to manage vendor contract compliance with timeliness and clarity.

Over the course of the pilot, May Mobility reporting improved with regard to service insights (e.g., headways and incidents), ridership totals and averages, customer support insights, and more detailed descriptions monthly autonomy heatmaps, as well as communication between May Mobility, RIDOT, and other research partners. However, lack of access to certain data impacted program operations and research capabilities.

As such, RIDOT and the TRIP research team were unable to explore key research questions, especially those related to autonomous technology. Provision of certain reporting information in non-machine-readable formats such as PDFs only on a monthly basis meant that certain information could not be easily queried by RIDOT staff, and was left out of the research and data warehouse or else had to be manually recreated by project staff in order to be included. Finally, lack of clear documentation of methodology for producing certain figures and metrics created confusion and undermined trust in reports. ●

Figure 5-2. May Mobility shuttle as represented on the Transit mobile application (Transit, n.d.)

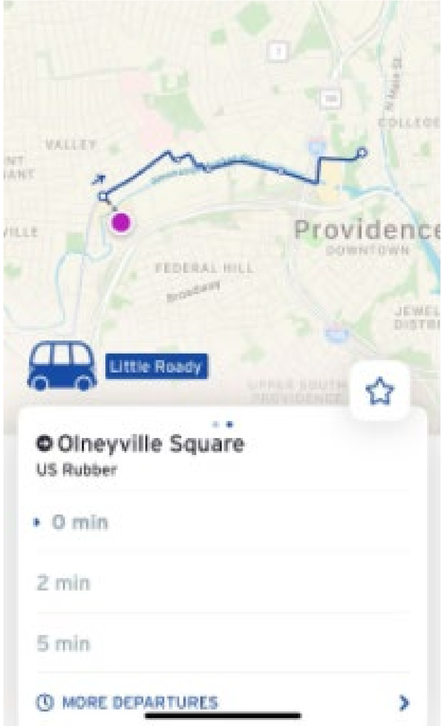


Table 5-1. Data sharing variables

Data Ask From RFP	Method of sharing or report (if any)
Total miles driven	Included in API
Miles driven in autonomous mode	Not reported
Miles driven in manual mode	Not reported
Time for operator to assume control	Not reported
Number and frequency of incidents and required operator interventions	No machine-readable data; partially reported in PDF
Number of manual disengagements	Not reported
Number of automatic disengagements	Not reported
Number of disengagements due to weather conditions	Not reported
Number of disengagements due to road surface conditions	Not reported
Number of disengagements due to construction	Not reported
Number of disengagements due to emergencies	Not reported
Number of disengagements due to accidents or collisions	Not reported
Number of disengagements due to unwanted maneuver	Not reported
Number of disengagements due to perception discrepancy	Not reported
Number of disengagements due to software discrepancy	Not reported
Number of disengagements due to hardware discrepancy	Not reported
Number of disengagements due to incorrect behavior prediction	Not reported
Number of disengagements due to road users behaving recklessly	Not reported
On-time performance (one minute early to five minute late)	Derivable from raw data shared via API
Number and length of any delays beyond five minutes, cause for delay	Derivable from raw data shared via API
Wait time for passengers	Derivable from raw data shared via API
Cost per hour to operate, cost per passenger	No machine-readable data; inconsistently reported in PDF, but not real cost.
Daily ridership statistics with detailed information on number of passengers per hour	Included in API
Number of passengers boarding and alighting by stop location	Included in API
Battery performance, range, degradation, charging time, operating efficiency	Raw data shared via API, but not usable due to data quality issues

Additional Data Shared (not requested in RFP)	Method of sharing or report (if any)
Real-time location of vehicles	Included in API
Defined route	Included in API
Stop locations	Included in API

Discussion

5.5. Public Partner Capacity

Given the complexities associated with establishing and implementing an innovative pilot of this nature, RIDOT accomplished significant goals (establishing the RFI, the expo, executing a public-private partnership RFP, etc.) in just over two years leading to the launch of the pilot.

Nonetheless, challenges encountered during both the contracting and operational phases point toward the need for additional capacity within the public partner team, especially during the early ramp-up stages of the pilot. Within the RIDOT team, there were originally two staff assigned to the project, which narrowed to just one staff member at the midpoint in December 2019. Of these staff, neither were dedicated full-time and were often splitting time on other programs and agency priorities. Provided how time consuming pilot management became, interviews indicated that a more dedicated team would have enabled more responsiveness to unexpected issues and allowed closer monitoring of the service and the research.

Negotiations surrounding data sharing did not involve the research team due to phasing of the contracting, and appeared focused on specific metrics instead of use cases. Presenting a map of the metrics to desired goals or learning objectives could have led to alternative solutions and outcomes. ●

5.6. Marketing and Outreach

Due to constraints around public-facing marketing and outreach regarding the service, communication about the shuttle was predominantly limited to a public launch event at the Rhode Island State House, a community town-hall meeting conducted early in the project, information about the shuttle and a real-time service map posted on the RIDOT website, and physical signs at stop locations.

During the service launch, RIDOT staff, assisted by 3x3's field research team, canvassed the Little Roady route to provide flyers and information on the service to businesses and other key establishments. Despite on-the-ground outreach prior to and just following launch of the service, interviews with riders and individuals involved in the project execution pointed to limited marketing after the May 15, 2019 launch to raise awareness about the Little Roady service among residents in Providence, particularly in the historically disconnected Olneyville district where residents were not aware that the service was for them. Instead, riders reported mainly discovering the service through its physical touchpoints such as street signs, spotting the vehicle, or chatting with the fleet attendants or the surveyors conducting the research.

Respondents indicated that the signage was underwhelming, particularly at the train station, where there were issues with passenger cars and others blocking the space. Word of mouth or online articles about the shuttle written by press were also mentioned as sources of discovery.

However, research uncovered a general lack of awareness about the service in that many respondents indicated that there was not enough advertisement or outreach about it, a factor that not only limited overall ridership but also participation in the survey and research.

> *"In terms of awareness, there was absolutely no awareness of it ... And there continues to be no awareness of it. There's no public information really about it that gets circulated, there's no promotion of it."*

May Mobility issued a Marketing Plan in March 2020 outlining a schedule for Phase I (March 2020–May 2020) and Phase II (May 2020–May 2021) that included issuing hard copy collateral, community events, advertising campaign (paid media), and social media but the majority was not executed following the onset of the COVID-19 pandemic.

5.6.1. General transit feed specification

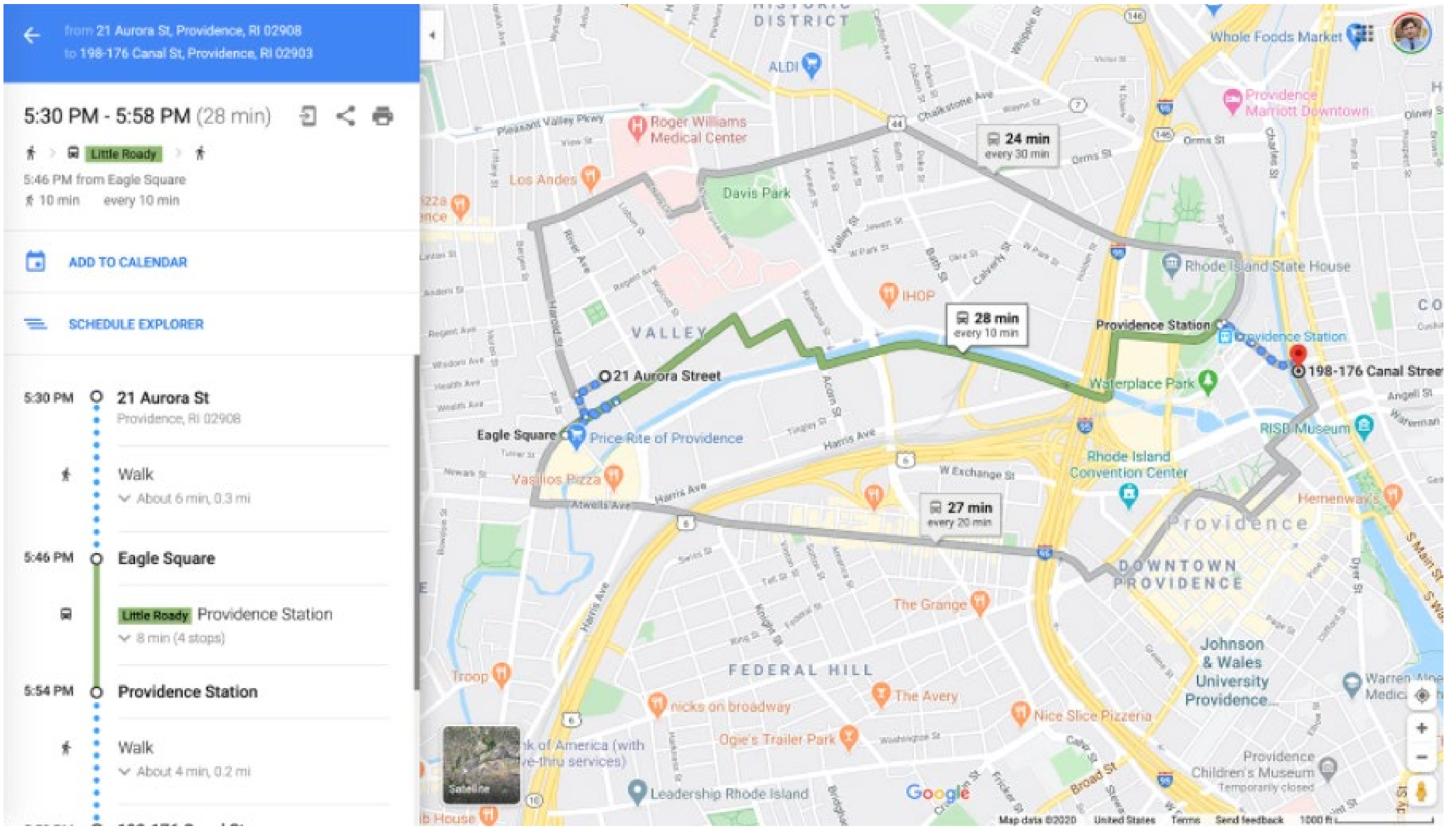
Beyond a lack of awareness about the shuttle itself, an additional barrier to shuttle ridership was lack of information about the schedule and route (i.e., where to find the schedule, how long wait times were, and where stops were located along the route). Among those who found the real-time map online, it was unclear where the shuttles actually were along the route and thus how long the wait time would be. Accordingly, the research team sought to transform and publish May Mobility data to conform with the General Transit Feed Specification (GTFS), the data standard through which public transportation agencies publish route and schedule information through trip planning apps like Google Maps and TransitApp.

Because so many travelers and commuters now use trip planning apps to make decisions about how to get around on transit, GTFS publication allows potential riders to discover and select routes and services, especially new routes and services like Little Roady (Figure 5-3).

Efforts to transform and test that data in a trip planning app alongside RIPTA partner, TransitApp, were made to allow users to discover Little Roady stops and for the Little Roady route to appear in query results when users search their trip planning app for public transit options for relevant origin/destinations in Providence.

Although the team was able to publish on TransitApp and Google maps, the process was time consuming and was not published until after suspension of the AV shuttle service. Although the Little Roady service was continued by RIPTA through the end of June, it is difficult to discern the role that GTFS played in service discovery due to significant ridership drops related to the COVID-19 pandemic and subsequent shutdowns and service changes. ●

Figure 5-3. Little Roady trip planning on Google Maps enabled by GTFS publication



from 21 Aurora St, Providence, RI 02908
to 198-176 Canal St, Providence, RI 02903

5:30 PM - 5:58 PM (28 min)

Little Roady

5:46 PM from Eagle Square
10 min every 10 min

5:30 PM 21 Aurora St
Providence, RI 02908

Walk
About 6 min, 0.3 mi

5:46 PM Eagle Square

Little Roady Providence Station
8 min (4 stops)

5:54 PM Providence Station

Walk
About 4 min, 0.2 mi

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6.0

Conclusions and Opportunities

The Little Roady shuttle pilot generated rich opportunities to explore the intersection of transportation services and technology from a myriad of vantage points. While every pilot project faces case-specific dynamics and contextual limitations, the Little Roady shuttle pilot nonetheless revealed important lessons related to the future of public transportation. This section includes conclusions drawn from the study as a whole, as well as suggestions for opportunities related to data sharing, future research and pilots, and longer-term planning.

6.1. Conclusions

6.1.1. Attitudes, perceptions, and rider experiences

The public has a sophisticated perception of where AVs could fit into the mobility system. The Little Roady AV shuttle received high rider satisfaction due to convenient headways, perceived energy efficiency, novelty, and riders' perceptions that the vehicle design was conducive to passenger conversation. Most riders believed that AV technology will be ready much sooner (in one to five years) than perspectives held by the general public.

Safety is a key concern about AV. Surveys and interviews indicate that there are positive expected future impacts associated with AV technologies related to efficiency and costs, but that these advancements come bundled with still unaddressed and growing concerns about privacy and safety. With regard to safety, which was recorded as the most important regulatory priority at multiple scales, concerns extend beyond the question of whether AVs can operate safely under typical operating conditions to how they are programmed to respond to conditions where value judgments are less clear. When pressed to make an immediate or emergency decision, how will occupant safety be prioritized relative to the safety of other drivers and pedestrians? Put more simply, for whom will AVs be safer?

Many user experiences were very positive, but also not directly AV-related. It can be argued that many positive findings related to user experience as associated with this project point more directly to aspects other than autonomy. The shuttle filled a specific gap in transportation, and did so in a format that was generally reliable, clean, uncrowded, friendly (via the small shuttle size and proximity to fleet attendants), and free to riders.

AVs increase, not decrease, the importance of user-centered design of the transit system for the most marginalized riders. The Little Roady shuttle was one of a small number of AV projects that have tried to serve a challenged area. But it failed to design the whole system—vehicle, accessibility, and the station environment. Introducing AVs will reinforce the need to think about the whole system for traditionally marginalized riders. The May Mobility shuttle did not allow for cargo, was not ADA compliant at the onset, and did not have a child seat. Families were unable to board unless they brought their own booster. Moreover, the curbside shuttle service stops were not adequately designed to provide potential riders with information about routes and the service.

6.1.2. Pilot performance and ridership

Ridership on the Little Roady shuttle increased steadily across the pilot period, even in the wake of the significant reliability challenges that plagued the program in the early months. The low number of riders left at stops and other factors indicate the shuttles were likely rarely operating at capacity outside of peak hours, but nonetheless, cumulative ridership indicates that ridership was relatively consistent throughout much of the week, and increased over time. Ridership understandably dropped drastically in the context of COVID-19 and following the abrupt and permanent service suspension by May Mobility in March 2020, following the transition to RIPTA-operated shuttles.

Operational challenges reduced shuttle reliability, but reliability improved over time. The Little Roady shuttle encountered a range of technological and mechanical problems in early operational stages that significantly reduced the number of vehicles in operation. The availability of performance metrics to RIDOT helped communicate the nature of these challenges and their impact on operations.

AV mode functionality appeared to improve, but many questions remain. In their monthly reports, May Mobility provided an overall impression of the challenges and dynamics associated with operating in AV mode, including specific examples of the types of conditions on the route that were associated with reduced AV mode use. These results indicate that AV mode use and functionality generally increased over the course of the pilot, and also that driver-related decision making about when to operate the vehicle in manual mode versus AV mode is a key factor. However, the strengths of these findings are limited significantly by the limited availability of data, which is discussed elsewhere.

Incidents were infrequent, generally not serious, often unrelated to AV, yet difficult to interpret due to data challenges. Based on analysis of May Mobility incident reports, the majority of incidents occurred while the vehicles were in manual mode as opposed to AV mode. A key apparent challenge with AV mode seems to relate to how it accounts for local driving norms related to intersections and yellow lights. The only known incident that involved an emergency hospital visit was associated with the vehicle stopping at a yellow light. Still, without a detailed presentation of AV mode data and a resulting reliance only on incident summary reports from May Mobility, the potential for analysis of these issues is limited.

6.1.3. Workforce development and fleet experiences

Little Roady fleet attendants brought to life many questions about changing roles and responsibilities among public transportation workers in the context of increasingly automated transit systems. The Little Roady pilot demonstrated the importance of fleet attendants, as they operated shuttles and served as a safety check related to automated processes as well as traditional mechanical aspects of shuttle operation. However, field data indicates that being partially unburdened by the task of complete manual operation, fleet attendants performed a variety of value-added functions associated with supporting a sense of comfort and safety among riders.

These findings point to a potential reconceptualization of the role of transportation workers as technical operators with knowledge of AV systems, competency with regard to driver safety practices, as well skill sets oriented toward supporting positive user experiences.

Fleet attendants reflected positively on their jobs, and RIPTA transit workers appeared optimistic about AV technology, but questions about the future remain. Little Roady fleet attendants reported a high degree of job satisfaction, and the RIPTA driver experiment indicated that direct experience with AV shuttles was negatively associated with concerns about AV-related job security. However, both of these findings are highly contextual and could relate to the specific characteristics of Little Roady operations at the time of the survey, as well as overall perceptions of job security among the small sample of RIPTA drivers. As such, questions about the nature and pace of adoption of AV technologies into public transportation networks necessitate a conservative interpretation of these results.

Notably, little is known about the nature of employment of May Mobility fleet attendants, including factors related to wages, benefits, and job security, among others, particularly in comparison to analogous conventional positions in the public sector. This lack of clarity around employment practices is particularly stark in the context of COVID-19, as it is unclear how fleet attendants were impacted by the sudden and ultimately permanent suspension of the May Mobility shuttle service.

Fleet attendants required ongoing training and incentives to limit taking control of the vehicle when driving slower on certain parts of the route in autonomous mode. Little Roady fleet attendants had the tendency to disengage the vehicle from autonomous mode on parts of the route that took longer or had multiple obstacles in the autonomous mode. A ranking model introduced by May Mobility that incentivized the number of miles driven in autonomous mode encouraged fleet attendants to only disengage the vehicle from autonomous mode when absolutely necessary. This indicates that ongoing training and incentives are important for fleet attendants to accept and trust the autonomous mode more.

6.1.4. Governance and management

Trialing AV technology as a form of transit in a complex urban setting demonstrates that the industry is not as ready may be indicated in media and by operators. To its credit, Little Roady was the longest active public AV transit route in the world and the first AV and EV public transit option available in Rhode Island (Bloomberg Aspen Initiative on Cities and Autonomous Vehicles, 2019). But observations surrounding Little Roady's AV performance and operational challenges suggest that AV technology—and AV transit as a service—is less well-positioned to become a near-term conventional transit option than many survey participants anticipated.

The largest observed cause for autonomous disengagements was unprotected left turns at 29.6% of incidents notated by the field surveyors. The RSUs were noted to be inconsistent and unreliable, particularly on rainy and windy days. There were also marketplace and supply chain limitations, as sourcing hardware continued to be an issue. Additionally, the ongoing need to update semantic maps was a challenge that required continuous manual adjustments to the software.

With AV service providers operating in a black box, the true costs to the public remain unknown. It can be argued that competition within the industry has driven resistance to transparency, especially as AV operators are vying to carve out their share of the market and over-inflating performance metrics to get ahead. Operators often cite concerns about data sensitivity and security but also fear performance metrics will be used against them, make them less competitive, or create perverse incentives. This is especially true for operators trialing AVs in more complex public service settings as opposed to relatively simple highway environments, for example. Opaqueness not only obscures the public sector's understanding of the implications of AV technology or how to effectively regulate it, but it also holds the industry back as a whole.

Public infrastructure to accommodate AV, C/AV, and EV technologies will be critical for advanced performance and widespread adoption and scaling. With the proliferation of private AV operators, the question remains about how they will play with the public sector moving forward. Particularly when the true cost of service delivery remains unknown, posing questions about longer-term equity, access, and privacy.

Diverging interests and objectives call for close attention to how public-private partnerships are structured if AV transit deployments are to serve a public good. Little Roady, one of RIDOT's limited public-private partnership projects, raises concerns about data privacy and ownership, safety standards and ethics, and equity and access, but also more broadly about how well poised private service providers are to provide a public good. May Mobility's abrupt service suspension of Little Roady in March 2020 left RIPTA to fill its void, an outcome that serves as a cautionary lesson that reveals weaknesses in public-private partnership models. As more jurisdictions seek to launch their own AV transit pilots or programs, such partnerships call for scrutiny of PPPs and potentially new models for piloting, and eventually adopting AV technology in service of public transit. ●

Conclusions and Opportunities

6.2. Opportunities

6.2.1. Data sharing and ownership

Absent federal regulation or reporting requirements, or clear industry data standards, it may continue to be difficult for state and local government agencies to work with AV operators to negotiate and agree upon data sharing terms to allow access to critical information needed to meet public interest research, policy, and planning objectives.

However, the successes and challenges of the Little Roady AV pilot's approach to data sharing offer lessons and opportunities for the field, particularly for state and local government actors seeking to build upon existing frameworks for AV data governance and reporting requirements. The below recommendations reflect these opportunities for continued piloting of new governance and data sharing models and approaches as the AV industry matures.

Require robust sharing of metadata and an inventory of data systems and sources collected or maintained by AV operators. Perhaps the fundamental challenge to robust AV data sharing ambitions observed during the course of the Little Roady pilot was unknown unknowns: it was difficult to talk about what data might be shared, and how, without a comprehensive understanding of what data is collected and maintained by AV operators like May Mobility.

A full accounting of data sources and systems via a required data inventory with robust metadata could go a long way toward educating the public, government officials, and policymakers. Such a data inventory might also foster more productive data governance and reporting conversations with industry about what data is available and potentially subject to reporting or oversight and consumer privacy protections.

Metadata should include an accounting of what data sources contain personally identifiable information (PII) or other sensitive information, what data sources contain proprietary business information, and what data might be available and needed to address government program, regulatory, or research needs. In 2019, RIDOT reviewed a U.S. Department of Transportation notice of funding opportunity for an Integrated Mobility Innovation (IMI) demonstration program with a focus on emerging mobility technology, service, and business models, including automated shuttles (U.S. Department of Transportation, 2019). Importantly, required application content included the provision of a preliminary data management plan (DMP) and a detailed description of terms associated with data collection, management, sharing, and usage.

While RIDOT did not pursue the opportunity, requirements of this nature signal the importance of consistent and transparent data agreements and practices. Moving forward, projects of this nature—regardless of funding sources—should incorporate uniformity and transparency of data in line with these requirements.

Map data sources to clearly defined research questions and use cases. A myriad of data is collected by AV operators, and most of this raw data is difficult to understand outside of its source system and internal business context. For this reason, AV operators must clean and filter raw data in order to share it with government partners, often with limited staff time as most technical staff are primarily focused on AV operation as opposed to data management. Providing clear research questions will make it easier for AV companies to determine the correct data and filtering and cleaning methodologies, as these may vary across use cases.

Thus, either prior to the issuance of an RFP, or via collaborative process with a selected AV vendor, local governments should identify, document, and clearly articulate key: (a) policy and research questions, (b) performance metrics, (c) program parameters, and (d) operational measurements. Each question, metric, or use case should include a defined audience or user and articulate the anticipated impact of data sharing. All data requested should then clearly map to an articulated use case.

Align early and explicitly on AV disengagement data reporting requirements, including agreeing on a level of AV disengagement granularity and appropriate context such as operational design domain (ODD) parameters. Vendors might be more willing to share disengagement data if: (a) ODD context is also standardized, (b) AV disengagements are aggregated to some summary level, and (c) AV disengagements are shared with independent researchers. Reporting of disengagements can be limited in value without the context of the ODD. One reason that AV operators like May Mobility may be hesitant to share disengagement data is that such data can be misleading without the greater context of the ODD. According to the SAE surface vehicle recommended practice standard known as J3016, the ODD can be defined as

> *"Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics." (SAE International, 2018, p. 14)*

In layman's terms, the ODD is the set of circumstances under which an AV operator expects a vehicle to operate autonomously. This is critical because it is one thing for a disengagement to occur when it is expected to due to ODD requirements not being met (e.g., an operational design domain does not include rain, and it starts raining) and an entirely different thing for a vehicle to disengage while operating within the bounds of the ODD (e.g., an ODD does not include rain, and it is not raining).

Moreover, different AV operators, and even different AV deployments, have different ODDs, making it very difficult to compare apples-to-apples. More transparency around the ODD of AV deployments by operators, as well as clearer articulation or even standardization of ODD requirements in service level agreements with government partners or permitting authorities could help in addressing this issue.

Establish data infrastructure and team data competencies to securely ingest, host, permission, and analyze large AV datasets. AV project teams should include data literate government staff who can interface knowledgeably with AV vendor data staff and audit and work with the shared data, including interfacing with data programmatically such as via an application programming interface (API) service. Adequate data infrastructure might include the set up of a data warehouse or similar system to provide controlled data access to key stakeholders such as academic researchers, policymakers, and government officials from various offices and levels of government impacted by AVs.

Utilize existing data standards, such as GTFS, to make service discoverable to riders via mobility apps as soon as the service launches. New pilot public transportation service routes are less likely to be known to the traveling public than established public transit lines, and, as we learned in the case of Little Roady, budgets for pilot and research projects may not include resources for marketing these new transportation options to the public.

The good news is that data can help make transit routes more discoverable. Increasingly, riders utilize trip planning apps in order to assess options and make travel plans. For this reason, the real-time data from May Mobility's API endpoint was utilized in order to produce a GTFS compliant data feed that was in turn ingested by the route planning applications Transit App and Google Maps. This developed organically out of ingestion of the May Mobility API by the Stae data management platform. However, it happened toward the end of the pilot, and after May Mobility operated AV service had ended, limiting the impact of a more discoverable service to only around a month and a half. Publication of a GTFS feed and subsequent appearance of the AV pilot service on route planning apps could have happened much sooner if it had been planned and if May Mobility's API were designed with this need in mind.

Transparency and uniformity of data via open data standards and interoperability will allow for comparison of technologies and assessment of maturity across pilots and, in the long run, help build public trust. As the frequency and forms of data tools increase across sectors, the National Association of City Transportation Officials (2019) recommends that cities include open data standards as prerequisites in development and procurement policies as means of reducing risks of becoming locked into proprietary tools. Open standards do not yet exist in the AV space, but they are desperately needed to drive many of the recommendations made here. For example, open standards could help ensure that multiple AV operators might collaborate on the provision of the same service and be evaluated in a consistent way. Future AV pilots should seek to move toward this goal by defining data specifications for various regulatory and operational use cases.

6.2.2. Governance and industry partnerships

The public sector can lead AV by setting precedents for the market to follow. Provided the novel nature of AVs, a lack of cooperation and fear of transparency has created a black box, limiting the public sector's understanding of the implications of AV technology or how to effectively regulate it. Meanwhile, in certain aspects, a lack of regulation and public investment in AV-related infrastructure puts the industry in a holding pattern as it waits to see which way the regulatory winds will blow.

Lack of transparency could be holding the industry back by limiting the advancement of the necessary support infrastructure, while the competition to advance autonomous capabilities stymies new creative applications of the technology, particularly in a public transit context. More genuine and tailored partnerships between private operators and public transportation entities could create pathways to more creative adaptations of technology and lead to more mutually beneficial and equitable outcomes. For example, AV could be applied in innovative ways to existing transit to improve safety, efficiency, and operator experiences. Such cooperative and incremental advancements might help to advance public infrastructure while simultaneously alleviating potential negative implications of AV technology, such as workforce development concerns.

Position early stage negotiations for setting up mutually beneficial public-private partnerships. In the near term, as cities, municipalities, and states are trialing out new AV transit programs, early stage negotiations and contracting are of vital importance to ensure the public partner has access to data and a certain degree of operational control over the service delivery. Pilot programs are valuable not only to test new services and technologies, but more importantly, to learn from them. It is important not only to identify metrics to be included in reporting but to identify use cases and research questions with which both partners can work together to answer. Third party providers and platforms also help to alleviate concerns regarding data aggregation and personally identifiable information (PII).

Design pilots from a bird's eye view to answer larger questions about the planning, policy, and regulatory implications of AV transit technology. While pilot programs might help answer local and pointed questions related to policy, regulation, and planning, by taking a piecemeal approach, they may fall short of helping to answer bigger picture questions. This is especially true if pilots continue to emulate unrealistic conditions without real-world complexity, for instance, on closed campuses. Little Roady was a notable contribution to the field in its aspirations to trial an AV shuttle service in a complex, urban setting and foster interagency coordination.

Although navigating risk aversion at this stage can be a challenge, more pilots should strive to address complexity head-on rather than play it safe. In the mid-term, publicizing insights gleaned through pilots and convening regular working groups to answer larger questions surfaced through such experiments will be important.

Make space for early and ongoing multi-stakeholder engagement. The multi-dimensional nature of AV transit technology and its implications for the public realm calls for a diverse, cross-cutting set of stakeholders to have a seat at the table. The more complex the pilot, the more interagency coordination may be required, which necessitates looking beyond officials who are charged with making and implementing transit policy at transportation agencies.

It is critical to investigate all possible implications and ensure individuals who will be affected or oversee policies or decisions related to AVs are at the table. This includes residents or commuters in the target area; elected officials; state-level actors such as the Governor's Office, Department of Motor Vehicles, safety officials, and insurance regulators; and local-level actors such as planning and infrastructure officials or other smart city stakeholders. Depending on the funding sources and location, federal entities may also need to be engaged in such as the USDOT, Federal Highway Administration (FHWA), Federal Transit Administration (FTA), and the National Highway and Traffic Safety Administration (NHTSA). Experts or other governing bodies that have implemented AV technology in their localities can be helpful by providing counsel.

Little Roady demonstrated the importance of engaging early on to coalesce partners with shared interests in exploring and learning from AVs, shape the elements of the program, and ensure the partnership was structured to learn from the deployment. It is also important to define use cases and research questions at this stage and clarify expectations surrounding involvement.

Early stage conversations to identify relevant factors for each organization, whether related to a need, impacts to stakeholders, potential for innovation, or policy impacts, may help to define clear roles and responsibilities. Carving out space throughout the process for partners to interpret findings and begin to surface opportunities and considerations related to their domain can help not only to enrich the findings but also help define subsequent pilot iterations.

Anticipate resource needs for the public transportation authorities. From the public partner lens, coordinating and managing an AV transit pilot is a time consuming endeavor that requires data fluency just as much as it does operational transportation experience. In the case of Little Roady, this largely fell on a small team, often without broader organizational support. It is suggested to ensure that there are sufficient dedicated staff and resources to manage AV deployments, particularly early in the process during contracting. Moreover, it is suggested to include a data scientist or equivalent on the project team to design a data and reporting schema and assist with data translation and negotiations as needed, or ensure that a research team is onboarded early to assist with the process.

Proactively approach safety, ethics, algorithms, and automated decisions. Interviews revealed a set of growing concerns related to encoded biases in automated decisions. This is particularly stark in AV technology, where decisions could mean life or death but are opaque and unregulated. Transparency from providers around programmed decisions and the mathematical models behind them is crucial.

Equally, research should be conducted to audit and identify patterns in decision-making related to AV technology to understand if algorithms are codifying biases, and to highlight the responsibility policymakers have to creating sound regulations. Academic support will be crucial, and working groups focused on AV transit technology should be convened to discuss implications and strategies for working toward a set of standards.

Collaborate with workforce leaders on the changing role of the transit workforce and fleet attendants in the context of an increasingly automated future. As driverless shuttle technology becomes more reliable, fleet attendants may no longer be required on all vehicles at all times—but their presence from time to time will still be an important part of delivering a safe, intuitive, and accessible transit service. For example, combined with real-time occupancy sensing, a floating pool of fleet attendants could travel the system—dispatched automatically to spot-check busy vehicles, route segments, and stops—providing assistance as they go. This is just one vision of the transitioning role of fleet attendants in the context of growing AV. As the scale of automation implementation increases, there is a diverse range of strategies for partnering with transit workers and unions to design labor force transitions that create value by redefining services and developing skills, rather than simply reducing headcount.

6.2.3. Opportunities for future exploration

Themes and opportunities to explore through further research or pilots:

Connected vehicles and "smart" technology infrastructure— Exploration of networked smart corridor infrastructure in future pilots may help advance AV performance and safety in complex urban environments, enhance rider experience, and set a precedent for the market to follow. Possible opportunities include enabling real-time communication using appropriate technology (e.g., C-V2X, dedicated short range communications [DSRC], or other), communications with first responder systems and/or infrastructure, smart signals, electric vehicle infrastructure for charging stations at a larger scale, and smart shuttle stations. However, the nature of data collection associated with smart infrastructure must include a methodical review of the privacy concerns related to data collection, analysis, and storage.

Questions include: How might connected vehicle and infrastructure technology relate to transit service safety and efficiency? What infrastructure changes or innovations are necessary to support AV or EV mobility services, particularly in urban environments?

Integrated multimodal networks and first/last mile solutions—For many riders, especially commuters to the Boston metropolitan area, Little Roady played the role of a first mile/last mile solution. As smaller-scale service experimentation with first/last mile routes becomes more economical and feasible, smaller vehicles could be a viable pathway to more efficiently service such routes without the need for extensive planning.

Consider route integration with existing alternative or microtransit modes (e.g., bike shares, scooters, ferries, etc.) to provide a holistic system of transit options, streamline rider experience, and promote mode shift. Little Roady demonstrated how novel modes of transportation have the ability to attract commuters and overcome public transit stigma. Move toward an integrated payment system across public and private transportation options by aligning with other systems and providers. It is important to consider options for unbanked or less technologically literate residents by providing ease of access to stations where cards for service might be purchased.

Questions include: What alternative modes are riders connecting to, and why? How are people getting to the route? What would help streamline their trip? What vehicle design standards need to be in place to accommodate multi-modal transit?

Unpacking the AV black box and data ownership—Investigate performance of AV technology and disentangle data ownership questions, especially when AV operators are subsidized through public taxpayer dollars. Frame pilots by mapping metrics to use cases and research questions, and securing robust data sharing agreements. Utilize third party

platforms as necessary to ensure PII is protected. Work toward a new reporting standard to support research needs by testing new methods for data sharing to support public transportation operators, planners, and civil engineers seeking to design safer, more complete streets and multimodal networks.

Questions include: What data are gathered through AV operations that might be useful to government functions (e.g., pothole data, midblock pedestrian crossings, street light outages, road obstructions, etc.)? How can the semantic map be less of a black box to government partners? How might the government support accuracy and portability of the semantic map? Is there any part of the semantic map that should be public domain? How might we pilot and evaluate a new reporting standard to support safety and research needs?

Flexible and resilient forms of microtransit—In the face of the COVID-19 pandemic, Little Roady endured a change in operators from May Mobility to RIPTA and experienced a sudden drop in ridership compared to pre-pandemic levels, which presented a unique opportunity to adapt to meet the needs of the moment. Explore AV microtransit as part of a more resilient transportation network, including the potential to realize a more adaptable mode of transit in response to changing community needs during crises.

Examples include providing flexible routes and schedules to accommodate essential workers or serving new purposes like delivery or freight through mixed-modes (e.g., freight/parcel and passenger services). Consider the potential for consolidated essential service routes along essential routes to support ongoing relief or business operations, including the unique potential of AVs to implement freight movement while maintaining strict social distancing. Investigate flexible route options and on-demand technology to accommodate multiple fixed routes that provide first/last mile connections with alternative modes of transport and adjust depending on demand.

Questions include: Where are smaller scale services best deployed? How can services adapt to changing needs and conditions? What new uses of shuttles could be accommodated to adapt to needs?

AV-augmented public transit—Assess the opportunities and considerations for how such technology will be integrated into public transit services and regulated. Interrogate how new creative adaptations or applications of technologies or service innovations can enhance existing public transit, including

fixed-route service, as well as how public transit agencies and authorities can be prepared for future transportation innovations. Weigh how AV, LiDAR, and EV technologies might impact the safety and efficiency of various transit services, including minimizing downtime and costs associated with collisions. Consider how to incorporate AV and other components into public transit operations, including fleet training, facility improvements, rider service experience adjustments, and transit asset management. Understand challenges and opportunities associated with how public and private partners can work together on service delivery to inform future partnerships.

Questions include: How can transportation innovations such as LiDAR, EV, and AV technologies be applied to traditional fixed route transit and larger transit vehicles? How should fare policy be addressed? How would the service be funded? What service standards should be established?

6.2.4. Advice for pilots in other cities

Develop a collaborative approach to data schema. Partner with institutional or research partners and select vendors prior to issuing an RFP or signing a contract to develop and align on a data schema with standardized definitions and ODD parameters, as well as provisions, to support data collection in a machine-readable format to measure performance metrics.

Methods for raw data cleaning should be clearly laid out through the data schema and mapped to different use cases. The data schema can become a guide for the government staff to interface knowledgeably with AV vendor data staff and work with data shared to raise questions and concerns, and to measure and assess performance.

Develop hiring requirements and conduct holistic training for operators. May Mobility fleet attendants (operators) played a role beyond their official capacity of operating the vehicles in cases of disengagement. They became the steward of not just vehicle safety and technology, but they communicated with passengers and intervened when the shuttle environment was disturbed. It is important for fleet attendant training to account not only for operational proficiency but also for communication, mediation, and safety monitoring practices, as well.

Plan for adjustments and build ambiguity tolerance in operations and service agreements. While there is a general agreement that AVs present major opportunities for public transit, the pathway to seamless deployment and operations of fully automated vehicles in urban environments is still rife with uncertainties. For example, local idiosyncrasies are often encoded into AV algorithms and may need to be adapted when transported into new contexts or environments. Adoption of AV transit technology while addressing community goals will require trial and error and simultaneous investigation of AV implications.

This level of uncertainty calls for an agile, flexible, and adaptable planning approach that allows for monitoring and adjustments of plans and pilots in an iterative and incremental manner. With the Little Roady pilot project, software updates, ongoing training of fleet attendants, and a focus on user centered experience gradually increased the comfort level of the passengers and made rides more enjoyable. Future pilots should develop service agreements that allow for ongoing adjustments and capacity building both at the technology and human resources level.

Connect pilots with other smart city initiatives. The Planning for the Smart Transit and Infrastructure System of the Future report (City of Providence, n.d.) was developed by the City of Providence to anticipate the disruption of technology and identify new strategies that maximize benefits and minimize negative impacts of AV technology as measured against community goals. Even though TRIP and the Little Roady project were led by RIDOT, the City of Providence already had the political will and had laid the groundwork for the formation of TRIP, the TRIP mobility challenge, and the deployment of the pilot project. Other cities should similarly pilot projects in connection with existing smart city initiatives and in alignment with growing political will for AV pilot deployments, as well as with long-term smart city planning in sight to potentially incorporate connected corridor elements to automated vehicle pilot programs.

Identify and pursue funding that allows for parallel and independent research. There are multiple organizations that provide accelerated funding to support public agencies and businesses that are carrying out innovative urban transportation and smart city projects that reduce resources and energy use. Examples include Center for Innovative Technology, Digital Curb, the U.S. Department of Transportation’s Automated Driving System Demonstration Grants, and Smart City Works Venture Lab. Cities and organizations should seek to not just fund development and deployment of autonomous vehicle pilots, but also research to ensure that the technology is developed with community goals in mind and that learnings are shared across different agencies toward a national framework that allows seamless operations across borders. Institutional partnerships should also be investigated to contribute to validate and compare the findings with other pilots and disseminate them to wider audiences.

Prioritize service discoverability and informative and targeted communications. Public perceptions play a crucial role in the wider adoption of new transit technologies such as autonomous vehicles. As Little Roady revealed, a strong aspect of fast user adoption is convenience. The study also shows that attitudes were more likely to be positive with an increase in awareness and interaction. Provided the novel nature of AV transit, communication is needed to reinforce that the service is available for the general public.

Future pilots should maximize opportunities for public communication about the service to encourage more ridership. Cities with large scale mobility as a service (MaaS) rollouts could integrate the pilot service early on for commuters and residents to learn about the service through the platform and show how it can save them money as well as time. Early conformity with GTFS publication of route and schedule information through planning apps such as Google Maps, TransitApp, and others could provide additional channels for trip planning. Community events could be used as opportunities to engage residents about the service while advancing research efforts. This in-person method could be particularly useful in neighborhoods where the public might not be aware of the service.

Make better use of depots. A substantial opportunity for exploiting automation was lost in the failure to automate parking functions at the AV depot, where operators reported playing a game of Tetris to arrange the vehicles efficiently. In fact, in Singapore and other places where bus fleet automation is being widely tested, depot automation is the first place for extensive deployment due to the high degree of site access control. Future pilots should include automated parking and depot operations as a way of reducing costs. This is an easy win for the project bottom line, and an opportunity to gain valuable field experience in a highly controlled setting.

6.2.5. Long-term planning considerations

Increase access to transportation and opportunity. The Little Roady shuttles served a largely Hispanic population with relatively low income levels, increasing the accessibility of the historically disinvested population to the benefits of AVs and opportunities closely linked with transportation such as employment, education, healthcare, and recreation. As such, the Little Roady project met key criteria associated with transportation equity projects in that it addressed community residents' transportation needs, increased access to key destinations (e.g., schools, grocery stores, workplaces, community centers, medical facilities), and reduced greenhouse gas emissions. Furthermore, and to May Mobility's credit, it employed mostly people from the surrounding area.

The Little Roady pilot provides a good example of how future smart city planning and AV pilots could take transportation dead zones into consideration or complement existing public transit services while thoughtfully implementing projects with access and equity in mind.

Future examples could include neighborhoods not yet covered in the transportation master plan, loops that circulate around a university or college campus connecting it to a relevant center, a route that travels through cultural locations to provide cultural tours, a loop that enables access to areas cut off due to construction projects, and greenways, among others.

Fill the first- and last-mile transportation gap. The hypothesis that AVs can provide first mile/last mile connectivity to the pilot was valid. Residents seemed to appreciate the pilot location choice since the Olneyville corridor is widely known as a transit desert. The small size of the vehicle allowed it to travel to locations where a conventional bus could not go. Urban and low speed vehicles such as the Little Roady shuttle have the potential to complement existing transportation services providing first- and last-mile connectivity or bridge transportation service during non-peak or night hours, functioning as a micro or on-demand circulator.

Pursue accessibility in vehicle design. There is a need for continued enhancements by autonomous mobility providers to fully comply with accessibility standards, especially for the autonomous vehicles designed for public passenger transportation. This need is echoed in the announcement by the U.S. Department of Transportation of awards of more than $41 million related to innovative technologies and the improvement of transportation mobility and access for people with disabilities, of which May Mobility received a $300,000 award for a project titled, *Independent Safety for Wheelchair Users in AVs* (U.S. Department of Transportation, 2021).

Successful projects of this nature could help riders with disabilities or families with young children take part as early adopters of autonomous transportation. Further, consideration should be given to allow for riders who use wheelchairs to be independent for the entire ride to allow for full automation in the future. If public partners push private partners to comply with ADA standards before investment, the manufacturing of ADA-compliant autonomous vehicles could become cheaper and easier sooner. Depending upon demand, a wheelchair prototype could be developed by the same vendor by removing a seat. For example, May Mobility developed a wheelchair prototype in 2019 that included accommodations for entry and exit, and secured the passenger wheelchairs once aboard the shuttle during the trip (Etherington, 2019).

Plan infrastructure for seamless AV transit deployments. Seamless deployment and operations of AV transit will require major changes to the infrastructure, particularly in urban environments. The provision of EV charging stations throughout the city is a start. As learned through Little Roady, most AV deployments benefit from connected vehicle technology such as V2V and V2I communications, which is especially true in higher speed uses. Cities should plan for infrastructure adjustments required to allow more connected communication between vehicles and infrastructure, such as signals, but also redesign intersections, lanes, and curbs for enhanced safety and energy efficiency. While planning for such infrastructural changes and design, repurposing the streets for other mobility options such as biking and walking should also remain a priority to allow for coexistence.

Develop a mobility strategy that balances the externalities of transportation. CAVs shaping the new mobility system give cities and municipalities opportunities to formulate strategies that limit negative externalities such as congestion and pollution, and increase transportation equity and access through dynamic road usage tax charges. As cities subsidize AV pilot testing, consideration should be given to testing of different tax charges and pricing models as well. Doing so could incentivize manufacturers to modify their fleet design, mix, and algorithms to maximize profit with those constraints in mind and share lessons learned into the system. ●

What's next for Little Roady?

In January 2020, the research team developed through a partner engagement process a range of emerging opportunities to explore with regard to a potential extension and expansion of the Little Roady service. Opportunities described here emerged from that effort and form a forward-looking strategy to build upon findings captured in this report.

Fleet conversion and workforce engagement—Investigate how RIDOT and RIPTA can prepare for future transportation innovations, such as how LiDAR, EV, and AV technologies can be applied to a traditional fixed-route transit fleet. Surface challenges and opportunities associated with fleet conversion to inform potential transformation or operational changes, including fleet training, facility and infrastructure adjustments, paratransit service, fare implications, rider experience adjustments, and weighing how AV technology may affect the safety and efficiency of RIPTA services.

Key components of this include engaging drivers that are transitioning back into regular RIPTA work as fleet attendants, and digging further into unpacking what needs to be considered to ensure workforce development protections.

Route expansion and network integration—As a form of micro-mobility, Little Roady presents an opportunity to provide linkages where there is a lack of public or fixed transit due to cost or low levels of ridership and to test new routes. RIDOT and its partners can take an experimental and holistic view for larger network integration to promote mode shift by exploring routes that fill transportation gaps related to first/last mile connections with existing RIPTA service or alternative modes such as bike shares, scooters, or ferries. With an understanding that COVID-19 may continue to affect ridership levels of public transit, an additional opportunity emerges to provide service along essential routes to support ongoing relief and business operations, including the unique mixed-mode potential of AVs to implement freight movement while maintaining social distancing. Possible routes include:

- along the Providence River through the Dean Street corridor;
- along the Woonasquatucket Greenway to enhance downtown connectivity;
- branching out or adding loops to the existing route to expand connectivity, such as through Brown University to Kennedy Plaza; and
- through the Jewelry district to the pedestrian bridge.

Integrated payment system—In line with the above focus on system integration, an opportunity exists to align with ongoing initiatives to move toward a digital single-fare card system that works with public and some private forms of transit. In tandem, explore payment integration for unbanked residents in a way that addresses digital literacy.

Connected vehicle infrastructure—Implement smart infrastructure and connected vehicle technologies to enable V2I and V2V communication along a smart corridor to enhance efficiency and safety along the fixed-route transit. Opportunities for connected infrastructure include smart signals, remote signal changes, and other DSRC applications such as communication with first responders. With an emphasis on rider experience improvements, partners may also consider implementing smart shuttle stations that provide shelter and Wi-Fi.

Data sharing standardization—Explore new modes for sharing data between public and private partners, including finding new ways to aggregate autonomy data. Use this process as an opportunity to align on a protocol that provides public sector partners with data gathered through AV operations that may be useful to support related civic functions, such as reporting potholes or street light outages to maintenance crews, road obstructions to traffic management teams, or data pertinent to transportation planners and civil engineers seeking to design safer and more complete streets. ●

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Appendix A: Incident Report Summary

The following incident report summary is compiled from May Mobility monthly and incident reports.

Summary	Intersection	Date	Lat	Long	Injuries	Passenger	Damage	Engineer Assessment
May Shuttle was side swiped by another vehicle.	Providence Pl at the Providence Place stop	6/12/19	41.8284	-71.4212	0	0	Cosmetic damage to left bumper	Following log review and hardware assessment, Engineering's conclusion is that the cause of the crash was operator error. The autonomous system performed according to current system expectations with stop departure lane merging requiring fleet attendant control to ensure safety.
May Shuttle was rear ended at Valley and Atwells.	Valley and Atwells	6/13/19	41.8247	-71.4395	0	0	Light cosmetic damage to rear bumper	Engineering log reviews drew the following sequence: At an intersection with a red light, the shuttle pulls forward behind another vehicle in lane that pulls forward. A third vehicle is following the shuttle. The lead vehicle stops at the light. The shuttle comes to a stop behind it. The third, trailing vehicle makes contact with the shuttle before trailing vehicle came to a complete stop. The May shuttle was in manual during this entire sequence. Following log review and hardware assessment, engineering's conclusion is that cause of the crash was by error of the other driver.
Single vehicle accident: May Shuttle hit the curb at Alco in manual mode. Fleet attendant reported he blacked out at the t-bar and struck the curb head-on.	Ironhorse Way WB (Alco WB stop)	7/1/19	41.8293	-71.4315	0	0	Major damage to front bumper and sensors. Vehicle totaled and permanently removed from service.	Following log review and hardware assessment, engineering's conclusion is that the vehicle was in manual and the cause of the crash was operator error.
May Shuttle made a hard stop at a yellow light turning red. A trailing vehicle rear ended the May Shuttle. The fleet attendant trainee was brought to the hospital by ambulance and was cleared by a doctor later that day. The light turned yellow with shuttle crossing over white line of intersection, leading to a hard stop. A Kia SUV rear ended the May Shuttle while following closely.	Intersection at Eagle and Valley	8/9/19	41.827417	-71.436436	1	1	Rear bumper and crash bar.	Vehicle was behaving as expected and stopped at a yellow light. Per internal discussion, the previous yellow light behavior was calibrated less conservatively following this incident.
May Shuttle was lightly rear ended by a vehicle that immediately drove off. A manual transmission Mazda behind the shuttle was rolling back and forth. At one point, as the vehicle was rolling forward, it lightly hit the May Shuttle (Mystery). The driver of the Mazda pulled up next to the May Shuttle, and fleet attendant let them know they hit the shuttle and should pull over. Instead the driver drove away. Two passengers were in the vehicle at the time. Very little damage done to the shuttle.	Park St. NB	9/28/19	41.827828	-71.417666	0	2	Light scratch on rear bumper	Following log review and hardware assessment, Engineering's conclusion is that the cause of the crash was by error of the other driver. All autonomous functions were working correctly, and the vehicle was in manual mode at the time of the collision.
A vehicle ahead of the May shuttle drove in reverse to let another vehicle ahead get around. The driver backed into shuttle. The May Shuttle was at complete stop at the time. The driver of the other vehicle drove away before information could be gathered.	Providence Place Mall North Entrance (Hayes St)	12/1/19	41.829234	-71.416544	0	0	Front bumper cracked	Following log review and hardware assessment, Engineering's conclusion is that the cause of the crash was by error of the other driver. ALl autonomous functions were working correctly, and the vehicle was in manual mode at the time of the collision.
Single vehicle crash with metal fence at Hemlock and Promenade; damage to the front passenger side of May shuttle.	Hemlock and Promenade	12/8/19	41.829604	-71.429832	0	0	Front passenger damage	Following log review and hardware assessment, Engineering's conclusion is that the cause of the crash was operator error. All autonomous functions were working correctly, and the vehicle was in manual mode at the time of the collision.
Fleet attendant rear ended a parked Honda Odyssey on Valley Street.	Outside 221 Valley St.	12/15/19	41.822916	-71.439816	0	1	Front bumper and front sensors	Following log review and hardware assessment, Engineering's conclusion is that the cause of the crash was operator error. All autonomous functions were working correctly, and the vehicle was in manual mode at the time of the collision.

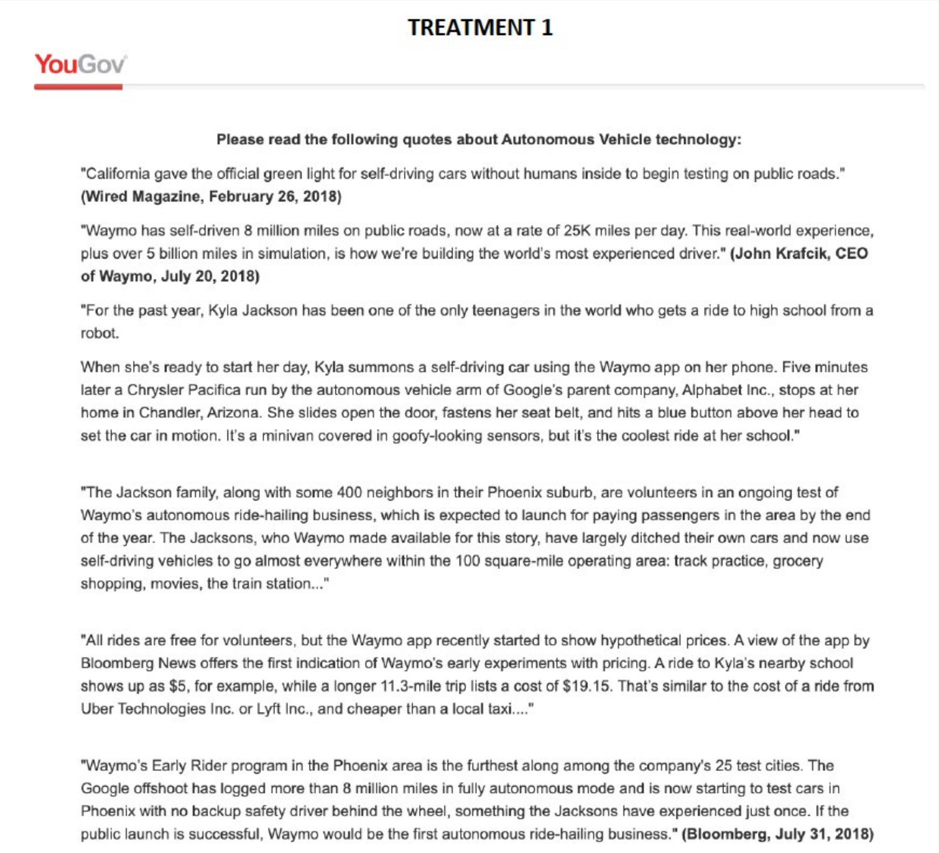
Summary	Intersection	Date	Lat	Long	Injuries	Passenger	Damage	Engineer Assessment
May Shuttle lost steering capability while beginning to cross the intersection. The fleet attendant avoided incident by slowing the vehicle to a stop as it approached the curb on the left side of the street at the far end of the intersection (Kinsley is a one-way during this stretch). The regular braking system was fully operational during this time.	Kinsley Ave and Dean St intersection	12/20/19	41.8289	-71.4266	0	0	None	1) The primary power supply for the steering motor failed to initialize at power-on. 2) The backup power system, part of May's safety system, operated as intended, providing power from a battery to ensure the vehicle could be moved to a safe location. 3) The power fault was detected by the autonomy system and the system performed as intended by not allowing the fleet attendant to enter autonomy mode. Alerts were sent to the base station. 4) The alerts at the base station were not noticed in a timely fashion, which led to the fleet attendant continuing to operate the vehicle in manual mode until the backup battery system was depleted. 5) The fleet attendant quickly brought the vehicle to a stop. Information regarding how the vehicle ended up on the sidewalk: The vehicle stopped quickly when the incident occurred, coming to a stop on the roadway (short of sidewalk), but in a place the fleet attendant felt was unsafe due to traffic conditions. The fleet attendant deliberately moved the vehicle farther out of the road way, up onto the sidewalk so as to not create a hazard for other road users. Corrective measures include: 1) Engineering quickly assessed that the power supply failure can be detected when the vehicle is turned on and that risk was very low provided that the onsite team verifies correct operation of the power supply before sending vehicles out. 2) Operation sites teams were informed of the urgency of monitoring of the base station for alerts. 3) On Monday, we are pushing out multiple automated mechanisms to increase the visibility and conspicuousness of such an alert if it should occur again, including in-vehicle alerts to the fleet attendant (both visual and auditory), and text message notifications to site staff in addition to the existing alert mechanisms.
Vehicle was parked at Eagle Sq. stop when it was rear ended by an elderly female. The woman was incoherent, and an EMT arrived on scene and took over. The police noted this.	Valley and Turner (Eagle Square stop)	1/7/20	41.825861	-71.439008	0	0	Crack in rear bumper	At 6:48 AM the vehicle pulls into the Eagle Square Stop autonomously. Hazard lights are activated by the autonomy system on approach to the stop and remain on through the duration of the incident. The vehicle comes to a stop as expected. Two vehicles pass by to the left of the May Shuttle in the normal traffic lane. There is at least a full lane's width between the May Shuttle and the yellow line. A third vehicle approaches from the rear on a trajectory towards the May Shuttle rather than around it to the left as the previous two vehicles. The vehicle decelerates significantly in the final meters of approach towards the May Shuttle, ultimately making contact at 6:49 AM. Following log review and hardware assessment, Engineering's conclusion is that the cause of the crash was by error of the other driver.
The May Shuttle was at a stop sign when it was rear ended by another vehicle. The other vehicle immediately left the scene.	Acorn and Kingsley	1/9/20	41.82843	-71.428579	0	0	Crack in rear bumper	All vehicle systems were operating as expected and per log and camera footage review, we judge the other driver to have been at fault for the collision. Review summary: The May Shuttle came to a stop at the stop bar for the stop sign on Acorn street (southbound) at Kinsley. Immediately upon coming to a complete stop the May Shuttle was contacted from behind at 10:34AM by another road user which had been following it in traffic.
May Shuttle was stopped at the US Rubber stop. Another vehicle drove too close and hit and damaged the May Shuttle mirror. The other vehicle did not stop and left the scene.	US Rubber stop	1/10/20	41.8266	-71.4382	0	0	Damage to mirror	Following log review and hardware assessment, Engineering's conclusion is that the cause of the crash was by error of the other driver. All autonomous functions were working correctly, and the vehicle was at a complete stop at the time of the collision.
Shuttle was stopped at a red light. When the light turned green it was rear ended by another vehicle before it began to accelerate. The other vehicle remained on the scene.	Valley and Atwells	2/25/20	41.824674	-71.439449				
Shuttle was in route when a bicyclist made impact with the right panel of the vehicle. Bicyclist gave information but left the scene.	Promenade and Dean	2/26/20	41.829237	-71.426826				

Appendix B: Additional Figures

Appendix b

B.1. Regional Experimental Survey Conditions

Figure B-1. Pro-AV condition



TREATMENT 1

Please read the following quotes about Autonomous Vehicle technology:

"California gave the official green light for self-driving cars without humans inside to begin testing on public roads." **(Wired Magazine, February 26, 2018)**

"Waymo has self-driven 8 million miles on public roads, now at a rate of 25K miles per day. This real-world experience, plus over 5 billion miles in simulation, is how we're building the world's most experienced driver." **(John Krafcik, CEO of Waymo, July 20, 2018)**

"For the past year, Kyla Jackson has been one of the only teenagers in the world who gets a ride to high school from a robot.

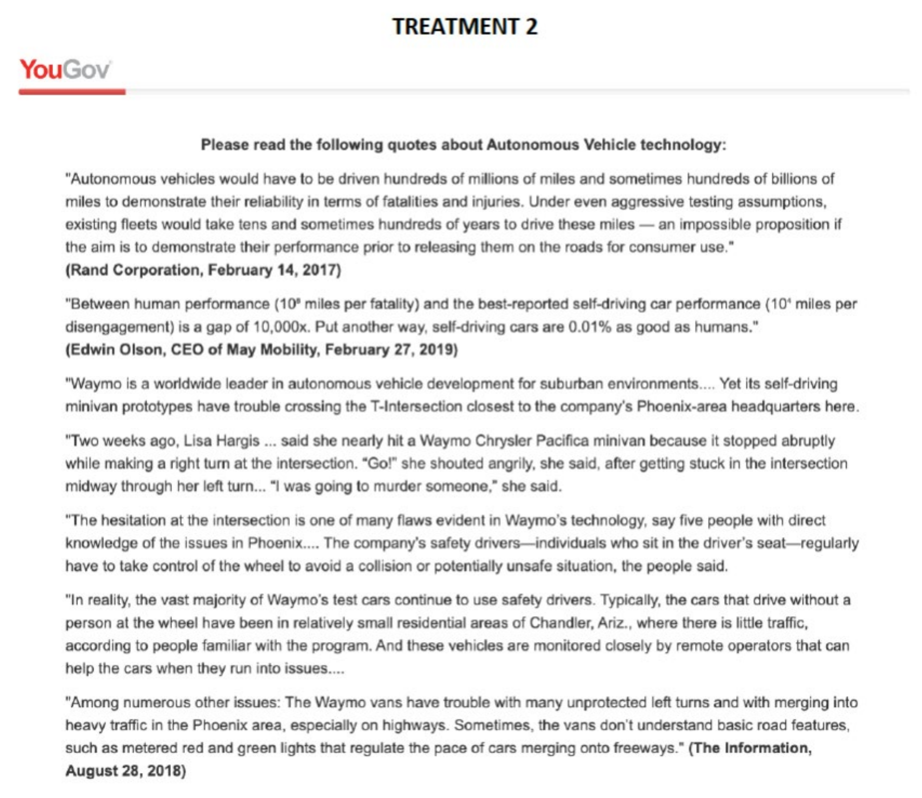
When she's ready to start her day, Kyla summons a self-driving car using the Waymo app on her phone. Five minutes later a Chrysler Pacifica run by the autonomous vehicle arm of Google's parent company, Alphabet Inc., stops at her home in Chandler, Arizona. She slides open the door, fastens her seat belt, and hits a blue button above her head to set the car in motion. It's a minivan covered in goofy-looking sensors, but it's the coolest ride at her school."

"The Jackson family, along with some 400 neighbors in their Phoenix suburb, are volunteers in an ongoing test of Waymo's autonomous ride-hailing business, which is expected to launch for paying passengers in the area by the end of the year. The Jacksons, who Waymo made available for this story, have largely ditched their own cars and now use self-driving vehicles to go almost everywhere within the 100 square-mile operating area: track practice, grocery shopping, movies, the train station..."

"All rides are free for volunteers, but the Waymo app recently started to show hypothetical prices. A view of the app by Bloomberg News offers the first indication of Waymo's early experiments with pricing. A ride to Kyla's nearby school shows up as $5, for example, while a longer 11.3-mile trip lists a cost of $19.15. That's similar to the cost of a ride from Uber Technologies Inc. or Lyft Inc., and cheaper than a local taxi...."

"Waymo's Early Rider program in the Phoenix area is the furthest along among the company's 25 test cities. The Google offshoot has logged more than 8 million miles in fully autonomous mode and is now starting to test cars in Phoenix with no backup safety driver behind the wheel, something the Jacksons have experienced just once. If the public launch is successful, Waymo would be the first autonomous ride-hailing business." **(Bloomberg, July 31, 2018)**

Figure B-2. Con-AV condition



TREATMENT 2

Please read the following quotes about Autonomous Vehicle technology:

"Autonomous vehicles would have to be driven hundreds of millions of miles and sometimes hundreds of billions of miles to demonstrate their reliability in terms of fatalities and injuries. Under even aggressive testing assumptions, existing fleets would take tens and sometimes hundreds of years to drive these miles — an impossible proposition if the aim is to demonstrate their performance prior to releasing them on the roads for consumer use."
(Rand Corporation, February 14, 2017)

"Between human performance (10^8 miles per fatality) and the best-reported self-driving car performance (10^4 miles per disengagement) is a gap of 10,000x. Put another way, self-driving cars are 0.01% as good as humans."
(Edwin Olson, CEO of May Mobility, February 27, 2019)

"Waymo is a worldwide leader in autonomous vehicle development for suburban environments.... Yet its self-driving minivan prototypes have trouble crossing the T-Intersection closest to the company's Phoenix-area headquarters here.

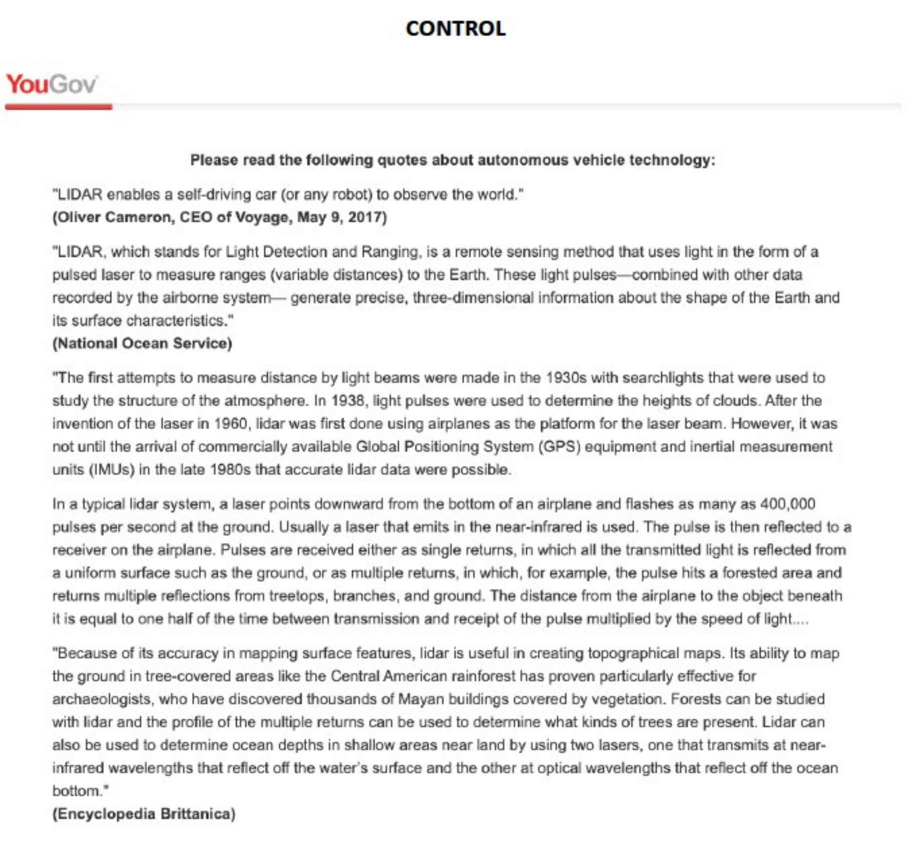
"Two weeks ago, Lisa Hargis ... said she nearly hit a Waymo Chrysler Pacifica minivan because it stopped abruptly while making a right turn at the intersection. "Go!" she shouted angrily, she said, after getting stuck in the intersection midway through her left turn... "I was going to murder someone," she said.

"The hesitation at the intersection is one of many flaws evident in Waymo's technology, say five people with direct knowledge of the issues in Phoenix.... The company's safety drivers—individuals who sit in the driver's seat—regularly have to take control of the wheel to avoid a collision or potentially unsafe situation, the people said.

"In reality, the vast majority of Waymo's test cars continue to use safety drivers. Typically, the cars that drive without a person at the wheel have been in relatively small residential areas of Chandler, Ariz., where there is little traffic, according to people familiar with the program. And these vehicles are monitored closely by remote operators that can help the cars when they run into issues....

"Among numerous other issues: The Waymo vans have trouble with many unprotected left turns and with merging into heavy traffic in the Phoenix area, especially on highways. Sometimes, the vans don't understand basic road features, such as metered red and green lights that regulate the pace of cars merging onto freeways." **(The Information, August 28, 2018)**

Figure B-3. Control condition



CONTROL

Please read the following quotes about autonomous vehicle technology:

"LIDAR enables a self-driving car (or any robot) to observe the world."
(Oliver Cameron, CEO of Voyage, May 9, 2017)

"LIDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics."
(National Ocean Service)

"The first attempts to measure distance by light beams were made in the 1930s with searchlights that were used to study the structure of the atmosphere. In 1938, light pulses were used to determine the heights of clouds. After the invention of the laser in 1960, lidar was first done using airplanes as the platform for the laser beam. However, it was not until the arrival of commercially available Global Positioning System (GPS) equipment and inertial measurement units (IMUs) in the late 1980s that accurate lidar data were possible.

In a typical lidar system, a laser points downward from the bottom of an airplane and flashes as many as 400,000 pulses per second at the ground. Usually a laser that emits in the near-infrared is used. The pulse is then reflected to a receiver on the airplane. Pulses are received either as single returns, in which all the transmitted light is reflected from a uniform surface such as the ground, or as multiple returns, in which, for example, the pulse hits a forested area and returns multiple reflections from treetops, branches, and ground. The distance from the airplane to the object beneath it is equal to one half of the time between transmission and receipt of the pulse multiplied by the speed of light....

"Because of its accuracy in mapping surface features, lidar is useful in creating topographical maps. Its ability to map the ground in tree-covered areas like the Central American rainforest has proven particularly effective for archaeologists, who have discovered thousands of Mayan buildings covered by vegetation. Forests can be studied with lidar and the profile of the multiple returns can be used to determine what kinds of trees are present. Lidar can also be used to determine ocean depths in shallow areas near land by using two lasers, one that transmits at near-infrared wavelengths that reflect off the water's surface and the other at optical wavelengths that reflect off the ocean bottom."
(Encyclopedia Brittanica)