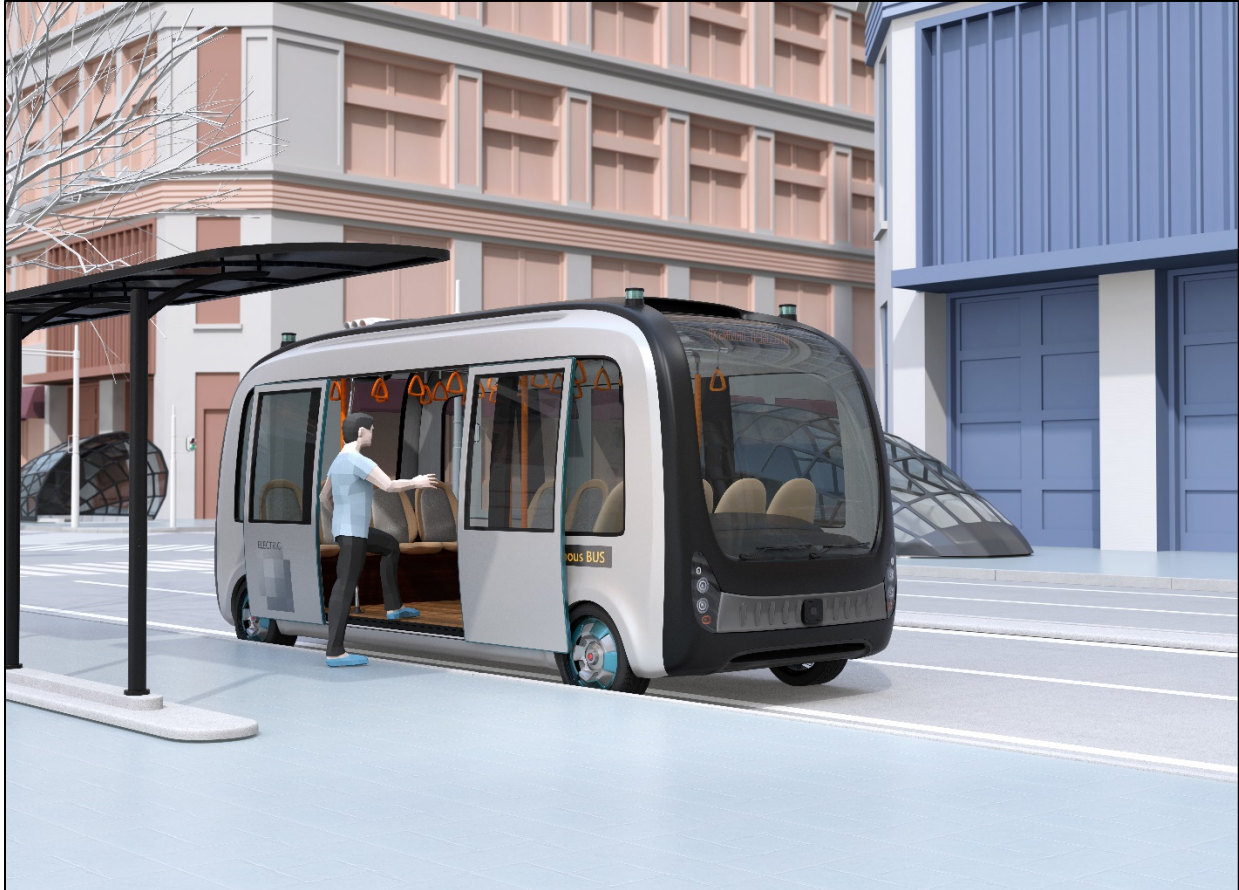# Transit Automation Technologies:
A Review of Transit Agency Perspective

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Disclaimer

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ABSTRACT

While the automobile industry is rapidly transitioning towards automation, the transit industry in the United States has recently begun investigating automation in transit operations. Multiple U.S. transit agencies have been experimenting with various automation technologies in transit vehicles. Examples of these technologies include lane-keep assist systems, collision avoidance systems, guidance systems for precise docking in Bus Rapid Transit, driverless shuttles (such as Navya, EasyMile, etc.,), etc. With various levels of transit automation technologies currently available and more advanced versions likely to be on the market soon, it is important to identify and understand transit automation technologies in the context of transit agencies' needs for implementing these technologies.

This study initially identified various U.S. transit industry uses of automation technologies and conducted a national survey of transit agencies in rural, small-urban, and urban areas to gather input about aspects of bus transit automated technologies and their implementation. A total of 258 responses were received from U.S. transit agencies; 157 responses from rural transit agencies, 67 from small-urban transit agencies, and 34 from urban transit agencies. Transit agencies believed transit vehicles with all Society of Automotive Engineers (SAE) levels (1 to 5) can promote safety. However, because safety of higher levels of automated transit vehicles (SAE levels 4 and 5) has not been extensively studied in all sizes of communities and types of environments, there were concerns and unanswered questions among some transit agency respondents about the technology's effectiveness, reliability, and performance. While levels 4 and 5 don't need to have a driver, transit agencies feel that the vehicles would still need an operator/agent to provide focused customer support and monitor the operating environment.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.   INTRODUCTION

Automated vehicle (AV) technology and connected vehicle technology is developing rapidly and fully automated vehicles are predicted to be on U.S. streets by 2020 (Business Insider Intelligent Estimates, 2015; Green Car Congress, 2017). Some form of AV technologies are already on the market, including automobiles with limited automated functions such as adaptive cruise control, automated braking, self-parking, lane-keep assist, collision avoidance features, drivers able to allow the vehicle take control on some roads/highways, etc. The transit industry is looking into AV applications as well. Transit operations in multiple U.S. cities have been experimenting with various types of AV technologies in transit vehicles. The technologies include: lane-keep assist systems, collision avoidance systems, guidance systems for precise docking in bus rapid transit, driverless shuttles (such as Navya, EasyMile, etc.,) etc. Currently, all these available AV technologies need the presence of a driver/vehicle operator for performing majority of the vehicle driving operations.

Some potential benefits of transit vehicle automation include enhanced safety, reduced liability, more efficient operations and maintenance activities, better service availability, reduced need for qualified vehicle operators, and reduced workload for vehicle operators using some kind of driver assist features (FTA, 2018). Transit automation technologies, if successfully implemented, can greatly enhance the mobility and quality of life of residents (U.S. DOT, 2018). Further, automated vehicles could also significantly change livability in small urban and rural areas by providing access to transportation services in a more cost-effective manner. While transit agencies have recently begun piloting and testing various automated transit technologies in their operations, many potential challenges have been identified, including: safety and security concerns, public acceptance and confidence, agency's willingness to implement these technologies, labor impacts, lack of funding for capital investment, and lack of enough research to boost confidence about safe transit operations with automated transit technologies (U.S. DOT, 2018). While the transit industry has recently begun to embrace the AV wave impacting the automobile industry, there is need for more research to create a better understanding of applicability of various automated transit technologies in U.S. communities, and address various challenges of implementing automated transit technologies through research.

While various levels of transit automation technologies are available, and more advanced versions will probably be on the market very soon, it is important to identify and understand transit automation technologies in the context of transit agencies' need for implementing them. At the same time, it is also important to understand the opportunities and challenges of implementing transit automation from information gathered from transit agencies that are already implementing or piloting various types of technologies. Data and feedback gathered from transit agencies can serve as a valuable resource for vehicle manufacturers, planners, and policy makers so they can better design automated transit vehicle technologies that can effectively meet the needs of transit agencies and, ultimately, transit riders. To address the research needs identified, objectives for this research effort are summarized below.

1.1   Study Objectives

There are three main study objectives for this report. They include the following:
1. Identify available driver-assist technologies and other transit automation technologies in transit bus operations. Summarize implementation and demonstration of various stages of transit automation technologies, primarily in United States.
2. Conduct a national survey of transit agencies in rural, small-urban, and urban areas to gather input about various aspects involved with bus transit automated technologies and their implementation.
3. Analyze the national transit survey data to understand opportunities, advantages, and challenges for implementing bus automated transit technologies.

1.2   Organization

The report is organized as follows.

Section 2 provides the review of bus transit automation implementation efforts in the U.S, and FTA's initiatives towards exploring the use of various vehicle automation technologies in bus transit operations. Section 3 describes the study methodology adapted for this research effort, which includes designing a survey questionnaire to gather input from transit agencies, validate the survey instrument with experts, and distribute the survey to transit agencies across the U.S. Section 4 summarizes the results of the national transit agency survey. Results are categorized based on rural, small-urban, and urban areas. Section 5 provides the summary and conclusions of the research effort.

2. BACKGROUND AND LITERATURE REVIEW

This chapter initially defines rural, small-urban, and urban areas; provides background information about various levels of automation as defined by the U.S. Department of Transportation (U.S. DOT); highlights Federal Transit Administration's (FTA) goals and strategic plan towards bus automation; and summarizes some implementations of the transit automated technologies in the U.S.

2.1 Rural, Small-Urban, and Urban Areas Defined

This study defines rural communities as those having populations of less than 50,000, small urban communities as urban communities as those with populations of more than 50,000, but less than 200,000, and urban communities as those having populations more than 200,000. This definition was established by the U.S. Census Bureau and is used by the Federal Transit Administration (FTA) for its funding programs.

2.2 Automation Standards (Society of Automotive Engineers (SAE) Levels Summary)

The National Highway Traffic Safety Administration (NHTSA) published a report "Automated Driving Systems 2.0: A Vision for Safety" to support automated vehicle technologies, and assist states in deploying the various technologies (U.S.DOT, 2017). The report also helps educate the public through a visual chart (Figure 2.1) that categorizes the various levels of driving automation for consumers. Categories range from SAE level zero (no automation) to SAE level five (full automation). These SAE levels of automation could help identify a specific SAE level attained by vehicle automation technologies. These SAE automation levels were used in the study to identify various categories of transit AVs.

SAE AUTOMATION LEVELS

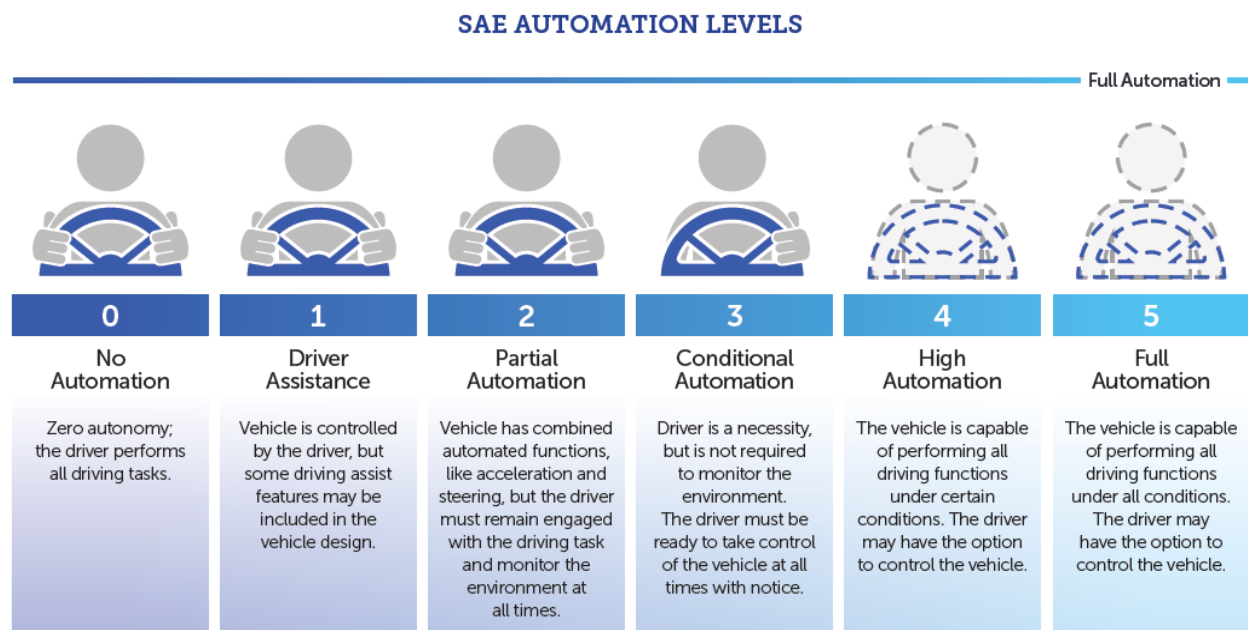| 0	1	2	3	4	5
No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Figure 2.1 SAE Levels of Automation from Automated Driving Systems 2.0
Source: (U.S.DOT, 2017)

2.3 FTA's Initiatives

FTA's Office of Research, Demonstration and Innovation began exploring the use of various vehicle automation technologies in bus transit operations to promote transit readiness for automation. Some of the goals in this effort included: "1) conducting research to achieve safe and effective transit automation deployments, 2) identifying and resolving barriers to deployment of transit automation, 3) leveraging technologies from other sectors to move the transit automation industry forward, 4) demonstrating market-ready technologies in real-world settings, and 5) transferring knowledge to the transit stakeholder community." (FTA, 2018). To support these goals, FTA developed a five-year Strategic Transit Automation Research (STAR) plan that was built based on extensive stakeholder consultation and use case analysis and is informed by a rigorous literature review. The scope of the STAR plan for bus transit automation ranges from collision-avoidance technologies for human-operated busses to full vehicle automation and includes everything in-between. FTA's STAR plan started in 2017 and will run through 2022. The three interrelated work areas incorporated in the STAR plan include enabling research, integrated demonstrations, and strategic partnerships (Figure 2.2). Five areas of use cases identified for the STAR plan include: transit bus advanced driver assistance systems (ADAS), automated shuttles, automated maintenance and yard operations, automated mobility-on-demand service, and automated bus rapid transit (BRT).
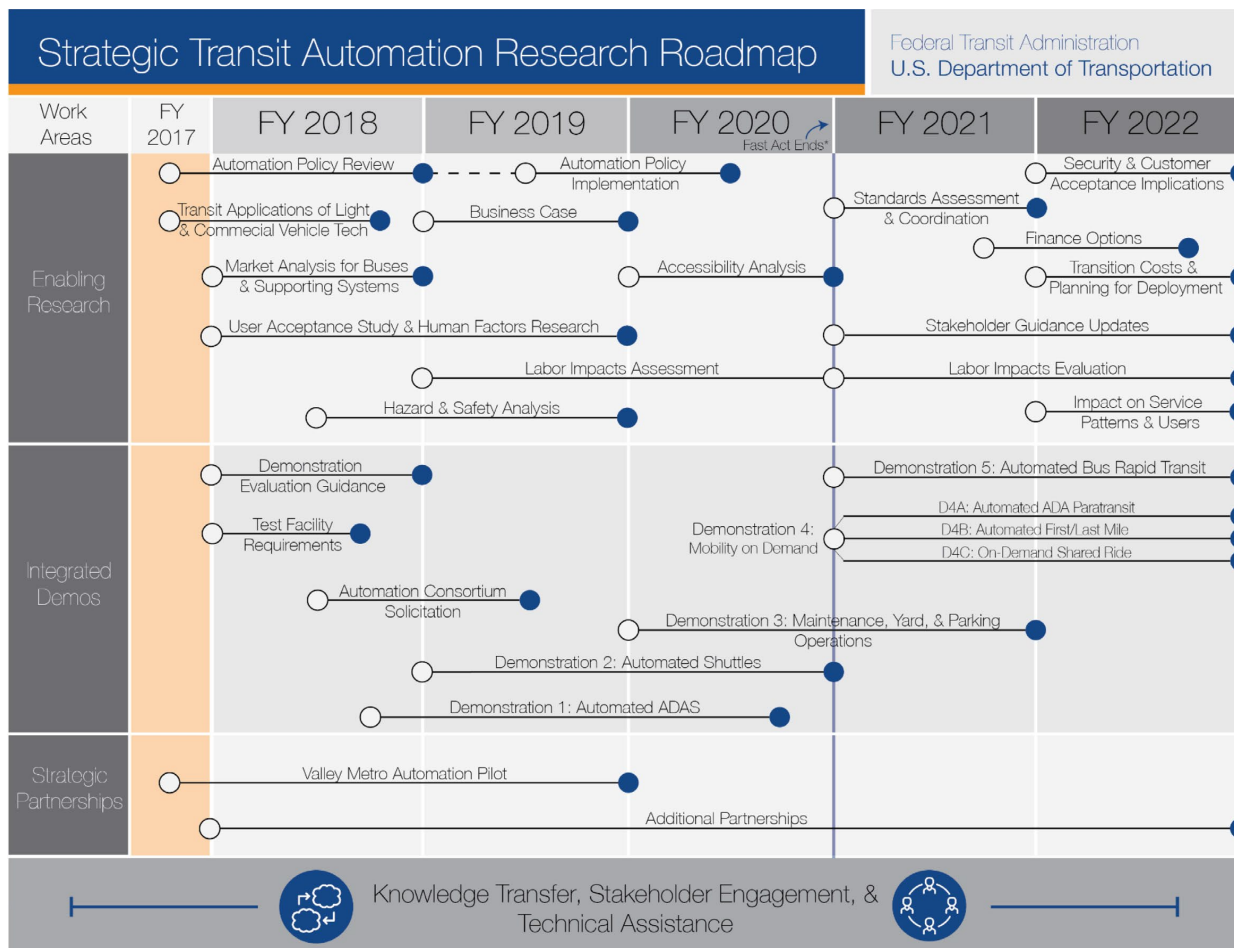

Figure 2.2 FTA's Strategic Transit Automation Research Roadmap Plan
Source: (FTA, 2018)

2.4   Transit Automated Technology Implementations in the U.S.

Automated technology implementation in the U.S. public transportation industry has been advancing through pilot programs, public-private partnerships, research lead by FTA, and through U.S. Department of Transportation Cooperative Research Programs. Further, in early 2019, U.S. Department of Transportation announced automated driving system demonstration grants to provide federal funding to support AV demonstration projects.

Transit automated technology applications implemented in the United States fall under various SAE level categories. Lower SAE levels of transit automation are usually referred to as advanced driver assistance systems (ADAS), and higher SAE levels (4 and 5) include driverless shuttles. Because transit vehicle operators manage more variables during their driving routines, ADAS features can reduce driver distractions, and potentially assist operators in achieving improved safety. ADAS technologies for bus operations includes features such as emergency braking for collision avoidance, precision docking, lane-keep-assist, curb avoidance, etc., Other advanced transit automation features that can be useful for conducting transit operations include platooning transit vehicles, automated maintenance and yard operations, and low-speed driverless shuttles. With regard to driverless shuttles, there is growing interest among cities piloting the shuttles to explore the potential opportunities for implementing the technology in local communities and transit operations. Some of the cities that are piloting or have already piloted automated shuttles include Detroit, MI; Denver, CO; Columbus, OH; and Las Vegas, NV (Teale, 2019). According to a 2018 U.S. DOT report, more than a dozen more pilots have been identified for funding and are in planning stages (Creggar, et al., 2018). Some of the low-speed automated shuttle providers who design and manufacture the vehicles are 2getthere, EasyMile, Local Motors, Lohr, and Navya (Creggar, et al., 2018). Communities piloting low-speed automated shuttles found that their pilot operations are helping educate the general public about AVs and are making them more comfortable. While the shuttle doesn't need an operator, considering the safety concerns of public with AV technologies, safety drivers were made available in the pilot shuttle operations to make sure that nothing goes wrong, as well as to educate riders about the technology, answer any questions, and help build confidence (Teale, 2019).

While there are diverse vehicle technologies contributing towards various levels of transit automation, it is important to understand that all the current implementations are either a demonstration or a pilot project. Some of the implementations of transit automated technologies in the United States include:
- FTA's $4.2 million grant to Minnesota Valley Transit Authority (MVTA) to demonstrate lane-assist technology for a BRT system. The automated feature on the bus alerts the operator if the bus drifts outside the lane by a visual alert followed by a seat vibration; if no action is taken by the operator, a motor on the steering wheel steers the bus to the center of the lane (Pessaro & Nostrand, 2011).
- FTA's $1.66 million grant to Pierce Transit to demonstrate collision warning on 176 buses, and automated braking technology on 30 buses. The collision avoidance system uses cameras to detect and warn bus operators of potential conflicts (APTA, 2019).
- Contra Costa Transportation Authority (CCTA) is experimenting with two EasyMile EX10 shuttles. EasyMile shuttles were initially tested in a closed test facility, followed by testing in parking lots, and later on a stretch of road between two parking lots with mixed traffic (Creggar, et al., 2018).
- Jacksonville Transportation Authority (JTA) has announced plans to revamp the existing elevated Jacksonville Skyway by operating automated shuttles and connect the elevated roadway with the ground level using ramps to reach additional destinations while potentially operating in mixed traffic. JTA has secured three shuttles (Navya, and EasyMile) which will initially be tested for six months in a closed facility (Creggar, et al., 2018).

- University of Michigan implemented an Navya Arma shuttle at the Mcity test facility for research, training, and tours. Later, two Navya shuttles were used in mixed traffic for a two-mile round-trip route (Creggar, et al., 2018).
- City of Las Vegas, Nevada used Navya Arma shuttle to provide shuttle service around a two-bloc loop in downtown with mixed traffic and high pedestrian activity. This one-year pilot project ended recently (APTA, 2019) (Teale, 2019).
- Minnesota DOT tested an automated shuttle supplied by EasyMile in its MnROAD test facility from December 2017 till January 2018. Because previous research and implementation of AV technologies were not conducted under winter weather conditions, Minnesota DOT tested automated shuttle operations in snow/ice conditions in the closed facility. Later, a public demonstration of the shuttle was made for a few days before the Super Bowl in Minneapolis, MN. The shuttle was also sent to demonstrations in five nearby communities (WSB & AECOM, 2018).

3. STUDY METHODOLOGY

The study methodology began with a literature scan to identify various bus transit automation technologies available in the United States. Next, the interest in various transit automation technologies in the transit industry is gauged by current implementations of available technologies and projects in the planning stage for adopting advanced bus automation technologies. While transit agencies may operate bus, rail, and ferry services, this study exclusively focuses on bus (or shuttle) transit operations and the potential for using bus automated technologies. Based on the input gathered from the literature review, a survey questionnaire was prepared to gather input from rural, small urban, and urban transit agencies in the United States to understand the scope and interest in implementing various bus transit automation technologies. The survey instrument focused on gathering data from transit agencies such as: familiarity with bus transit automation technologies and current implementations in the industry, interest in adopting various bus automated technologies for different types of transit services, potential opportunities for implementing bus automated technologies in respondent's transit agency, and advantages and disadvantages of bus automated technologies for traditional transportation services such as fixed-route, demand-response, and paratransit services. Interest is also gauged for using various bus/shuttle automated technologies for other transit and transportation services.

Experts in the field of transit, transit vehicle automation, and representatives from other relevant organizations were invited to review the survey instrument. Seven experts (list of participants provided in Appendix A) participated in the survey review process. The authors of this research effort collaborated with various organizations as partners to gather comprehensive data that would be beneficial to the current study to the partners. Partners for this research effort include Federal Transit Administration (FTA), Center for Urban Transportation Research (CUTR), and John A. Volpe National Systems Center. The study's research objectives align with the FTA STAR plan's research aims, so the authors contacted representatives from the FTA's Office of Research, Demonstration and Innovation to review the survey instrument and make any additions/modifications to make sure the information gathered would be useful to the FTA as well as a national transit audience. Researchers at CUTR were planning to conduct similar study. After learning about this study, the CUTR team collaborated with SURTC to coordinate the survey and its results. Similarly, the research team at John A. Volpe National Systems Center was also interested in the study results and has helped the SURTC research team with the survey instrument review process. Based on the feedback received from the survey review team and study partners, modifications were made to the survey instrument to gather precise input from transit agencies that could potentially be useful to transit agencies, transit stakeholders, planners, policy makers, and transit vehicle manufacturers. A copy of the survey instrument is available in Appendix B.

The survey instrument was hosted online using Qualtrics software, and was distributed using multiple vehicles in November 2018. SURTC has a transit agency database which includes contact information and other details of rural, small urban, and some urban transit agencies in the United States. The SURTC database was primarily used to reach out to transit agencies. Further, the survey was also distributed through Community Transportation Association of America's (CTAA) FastMail, which is CTAA's bi-weekly publication. The survey instrument targeted transit agencies' director of planning or chief operating officer. A total of approximately 1,700 agencies were contacted and 258 agencies responded resulting in a survey response rate of 6.8%.

4. SURVEY RESULTS AND ANALYSIS

A total of 258 transit agencies responded to transit agency survey to provide input about bus transit automated technologies, information about current implementations, and their interest in potential implementations in the near future. Among the 258 transit agency responses, more than half are rural transit agencies (157 responses), and the rest are small urban agencies (67 responses), and urban agencies (34 responses). Figure 4.1 summarizes various modes of bus transit services provided by rural, small-urban, and urban transit agencies that responded to the survey. The rural transit agencies that responded mostly operated demand-response service (72%), and the small-urban and urban transit agencies that responded mostly operated traditional fixed-route service.
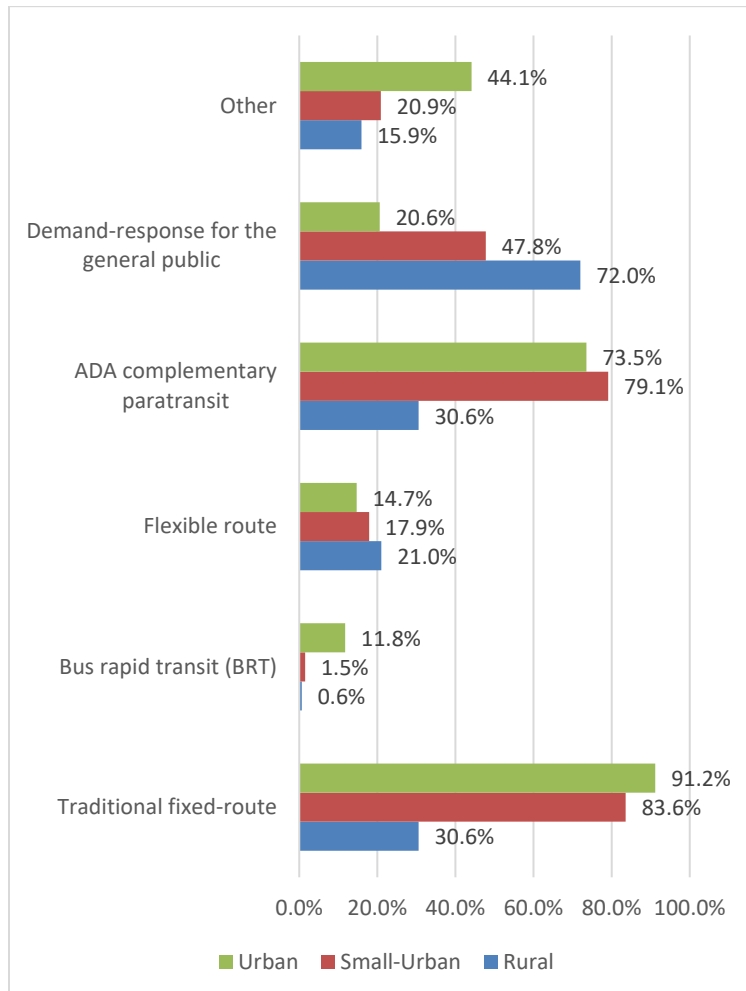
Figure 4.1 Type of Bus Transit Services for Rural, Small-Urban, and Urban Transit Agencies Responding to the Survey

4.1 Awareness of Transit Automated Technologies

Before asking specific questions about various bus transit automated technologies and the potential for using these technologies in the transit agency's operations, a few questions were included at the beginning of the survey to gauge respondents' knowledge about: 1) transit automation in general, 2) current technologies that are used in transit operations, and 3) FTA's plans in the areas of transit automation.

Transit agencies were asked about the awareness of various SAE levels of vehicle automation, and most of the rural transit agencies (65.2%) were not aware of them (Figure 4.2). Awareness of SAE levels of automation increased among transit agencies as they moved from rural to urban. Most of the urban transit agencies either know about the SAE levels of automation in detail or in general (Figure 4.2).
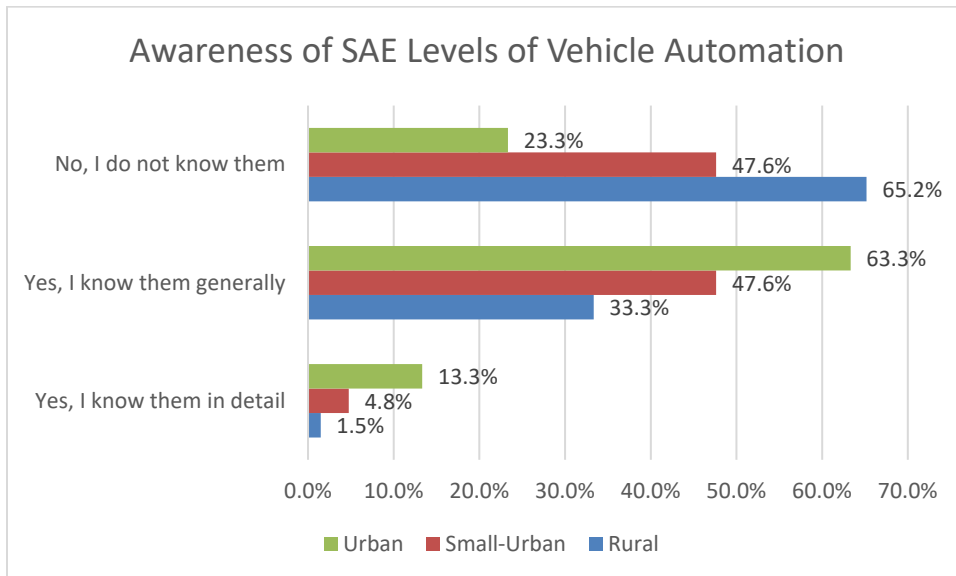
Figure 4.2 Awareness of SAE Levels of Vehicle Automation Among Rural, Small-Urban, and Urban Transit Agencies

Similarly, transit agencies were asked about their familiarity with FTA's STAR plan that strategically supports the development and deployment of automation technologies in U.S. bus transit operations. A similar trend was observed with a very low percentage of respondents from rural transit agencies (12.7%) and small-urban transit agencies (15.9%) being aware about the STAR plan, and almost half of the respondents (43.3%) from among urban transit agencies being aware of the plan (refer Figure 4.3 for details).

Figure 4.3 Familiarity with the Federal Transit Administration's STAR Plan

Apart from the above two measures to gauge the awareness of transit automation technologies, transit agencies were also asked about the awareness of low-speed fully automated shuttles such as Navya, EasyMile, etc., as their launch and operations in Las Vegas, Michigan State University, and other locations in the United States had been featured heavily in the news by the time this survey wa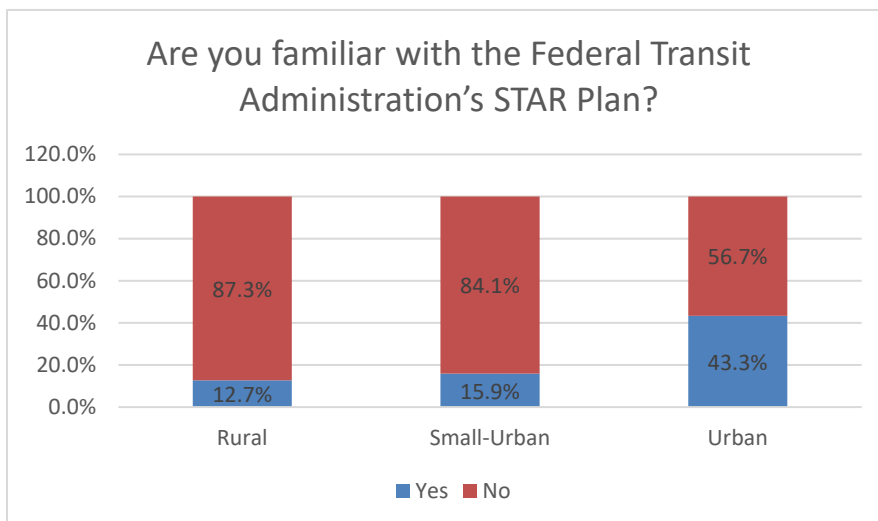s conducted. When compared to the previous two measures used to gauge the awareness of automated transit technologies, higher percentages of transit agencies in rural, small-urban, and urban areas were aware of the fully automated shuttle operations (Figure 4.4). The higher levels of awareness with the fully automated shuttles when compared to other measures (SAE levels of automation, and FTA STAR plan) could potentially be because fully automated shuttles received heavy media attention which helped increase awareness of these technologies to everyone, including transit agencies.
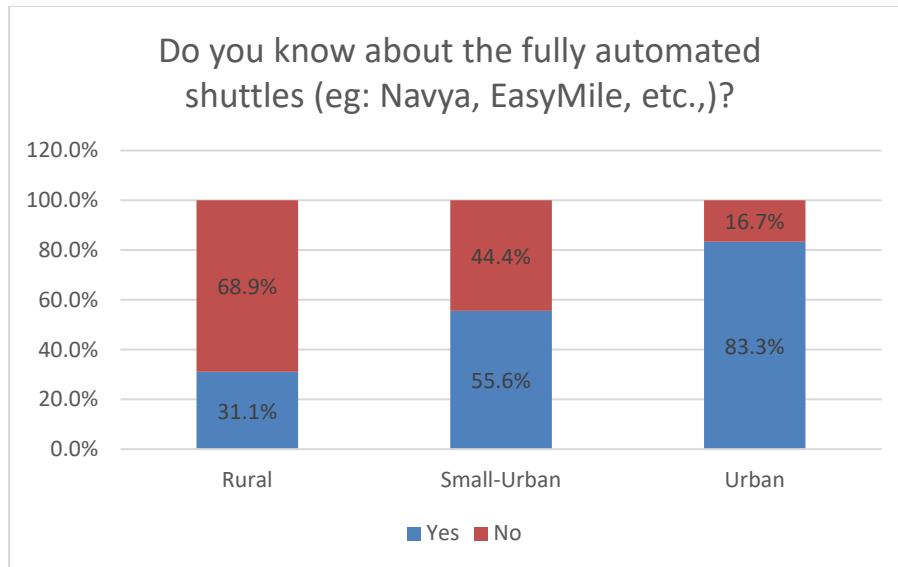
Figure 4.4 Familiarity with Fully Automated Shuttles

Transit agencies were also asked about transit buses with Advanced Driver Assistance System (ADAS) (SAE Level 1-2) which have automation features such as narrow lane/shoulder operations, collision avoidance using automatic braking systems, precision docking at BRT stops, platooning, curb avoidance etc., Awareness of transit ADAS technologies is summarized in Figure 4.5 and awareness of this technology was similar to fully automated shuttles. It could be summarized from the few initial survey question responses that market-ready technologies, and successful implementations help increase awareness and outreach of transformative technologies to both small and large transit agencies. Further, successful demonstrations of sophisticated technology could boost confidence among transit operators and potential riders.

Figure 4.5 Familiarity with Advanced Driver Assistance Systems

4.2 Fully Automated Shuttles

When the survey was conducted in November 2018, one responding small urban transit agency, and four urban transit agencies mentioned "they currently operate or plan to operate fully automated shuttles" such as Navya or EasyMile in the near future (Table 4.1). However, 14 rural 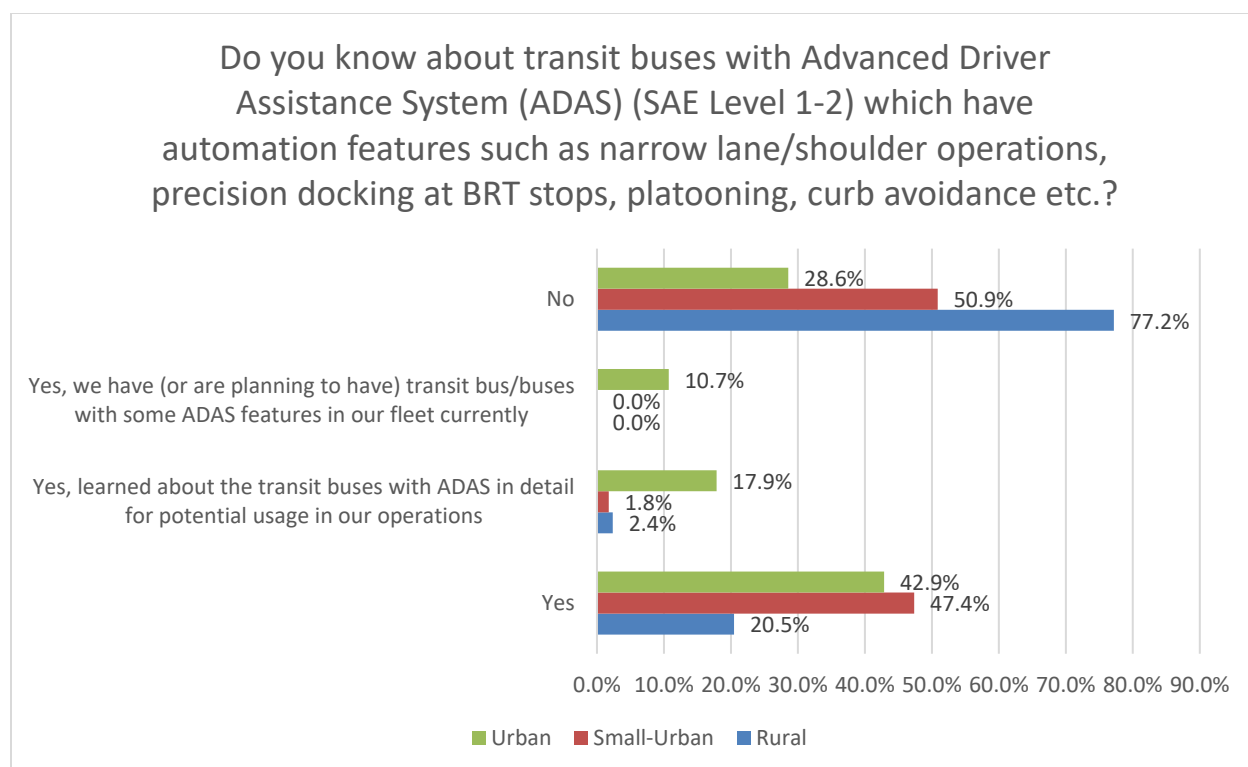transit agencies (10.4% of respondents), eight small-urban transit agencies (12.7% of respondents), and nine urban transit agencies (30% of respondents) mentioned they "maybe" willing to operate fully automated shuttles in the near future. Appendix C lists all the transit agencies that responded that "they currently operate or plan to operate fully automated shuttles." Most of the transit agencies (89.6% rural, 85.7% small-urban, and 56.7% urban) do not plan to operate fully automated shuttles in the near future.

Table 4.1 Does your agency currently operate, or plan to operate in the near future, fully automated shuttles?

	Rural	Small-Urban	Urban
Yes	0 (0%)	1 (1.6%)	4 (13.3%)
Maybe	14 (10.4%)	8 (12.7%)	9 (30.0%)
No	121 (89.6%)	54 (85.7%)	17 (56.7%)

Most (89.6%) rural transit agencies are not interested in operating fully automated shuttles now or in the near future (Table 4.1). Some concerns of rural transit agencies are: 1) not having enough supporting infrastructure in rural communities to operate a fully automated shuttle, 2) having a smaller transit system that cannot afford fully automated shuttles, 3) not having enough ridership to support the system, and 4) potentially could not be valuable for their clientele as their riders need more personalized service which includes help getting in and out of the vehicle if needed. However, few rural transit agencies were interested in these fully automated shuttles, curious to learn about automated shuttle's potential in their

rural community with their community's unique limitations, or wanted to explore opportunities in the near future provided a funding source is available. Small-urban transit agencies have a similar trend, with 85.7% of responding agencies not interested in the fully automated shuttles now or in the near future, and few agencies interested and curious to learn about the potential for its operations in their communities. In contrast, Urban transit agencies are comparatively proactive in exploring fully automated shuttles. Many had either already implemented fully automated shuttles, were planning for pilot operations based on secured grant/funding, or were looking for grant/funding opportunities to introduce automated shuttles in the near future. Most urban transit agencies seem to have already begun the discussion about integrating fully automated shuttles in some of their operations. Urban transit agencies that are not actively pursuing fully automated shuttle operations fall under one or more categories: 1) waiting for results from other successful demonstrations before they plan to deploy, 2) delayed implementation because of the lack of funding, and 3) want to think about automated shuttle operations in the future. Figure 4.6 summarizes how transit agencies in rural, small-urban, and urban areas could potentially use fully automated shuttles for various traditional bus transit services. While most transit agencies in rural, small-urban, and rural communities do not plan to use fully automated shuttles for traditional transit services, there is some interest in potentially using the shuttles for all traditional bus services except for ADA paratransit services. Figure 4.7 presents input from transit agencies about other potential services for which fully automated shuttles could be used in rural, small-urban, and urban areas. Transit agencies seemed much more favorable toward incorporating fully automated shuttles for circulator service, shuttle service on various campuses and airports, and serving low-density areas when compared to using the shuttles for traditional bus services. The top five services that rural, small-urban, and rural transit agencies potentially see as an opportunity to use fully automated shuttles are presented in Table 4.2. It can be observed that services such as downtown or business park circulators, shuttles on university campuses, and circulator bus services are best-use cases of fully automated shuttles in any type of community (rural, small-urban, or urban).
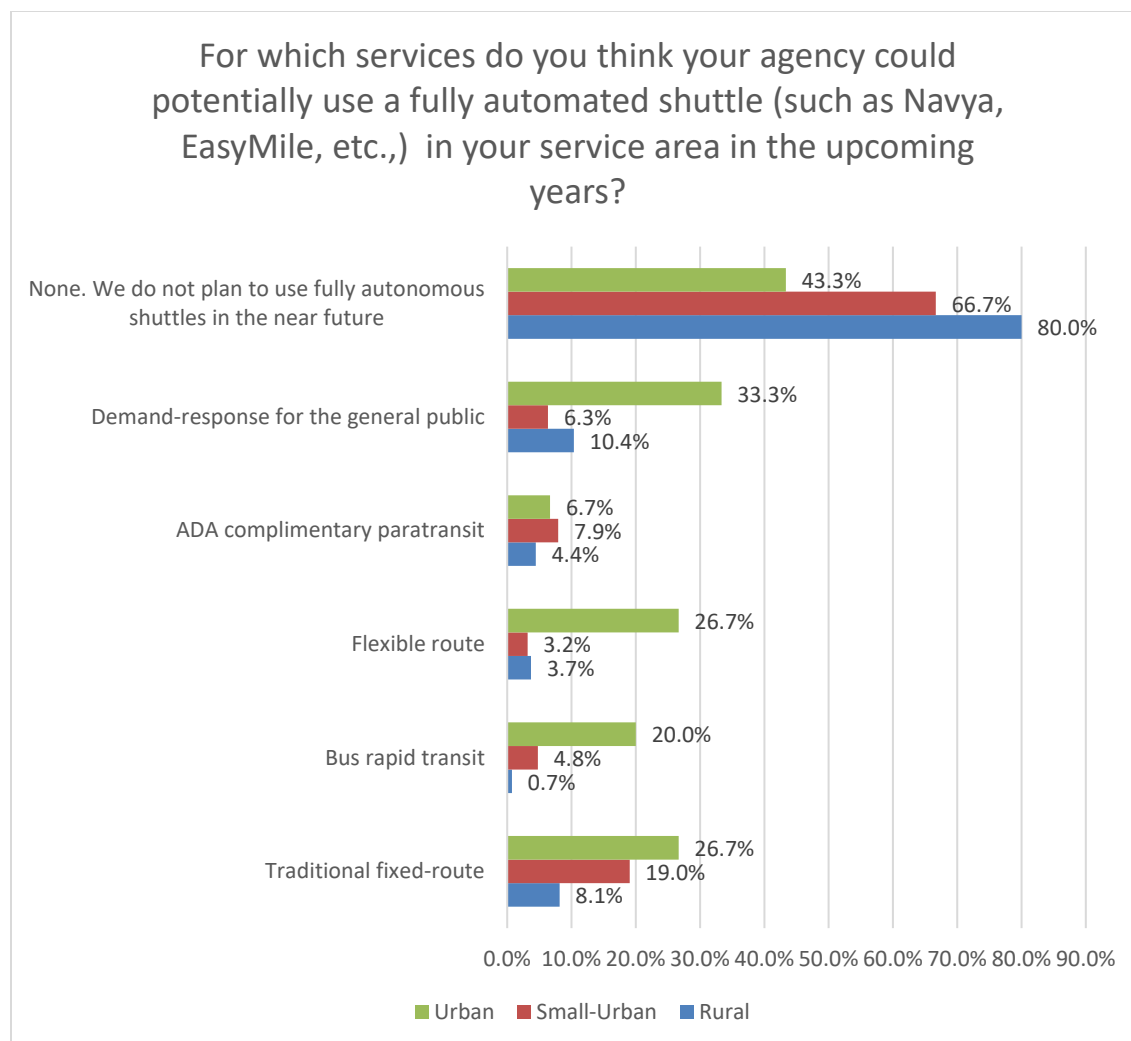
Figure 4.6 Potential uses for Fully Automated Shuttles in Traditional Bus Transit Services
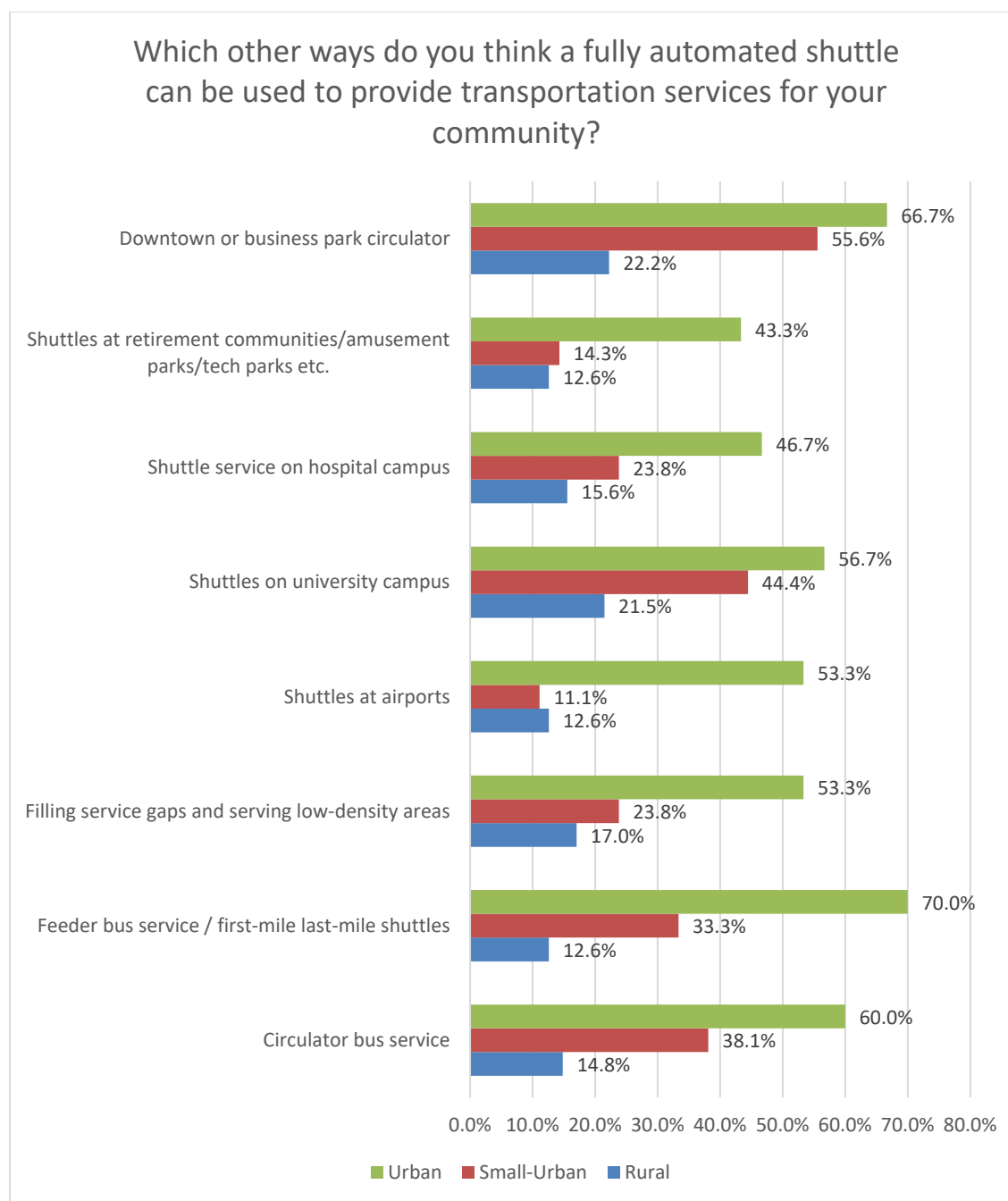
Figure 4.7 Potential Uses for Fully Automated Shuttles in other Transit Services

Table 4.2 Top Five Potential Transit Service Applications for Fully Automated Shuttles in Rural, Small-Urban, and Urban Areas.

Rank	Rural Areas	Small-Urban Areas	Urban Areas
1	Downtown or business park circulator	Downtown or business park circulator	Feeder bus service/ first-mile last-mile shuttles
2	Shuttles on university campus	Shuttles on university campus	Downtown or business park circulator
3	Filling service gaps and serving low density areas	Circulator bus service	Circulator bus service
4	Shuttles on hospital campus	Feeder bus service/ first-mile last-mile shuttles	Shuttles on university campus
5	Circulator bus service	Filling service gaps and serving low density areas	Shuttles at airport

4.3 Interest in Transit Automation Technologies

Once technology is ready to deploy, 30.7% rural transit agencies, 54.4% small-urban transit agencies, and 89.3% urban transit agencies believe that transit vehicles with automated functions would be beneficial for conducting some form of transit operations (Figure 4.8). However, 33.5% of rural transit agencies, 31.6% of small-urban transit agencies, and 10.7% of urban transit agencies are not yet sure. Proper outreach to provide information on relevant and effective automated technologies for potential operations along with numerous successful demonstrations can boost confidence in transit automation technologies among transit agencies.
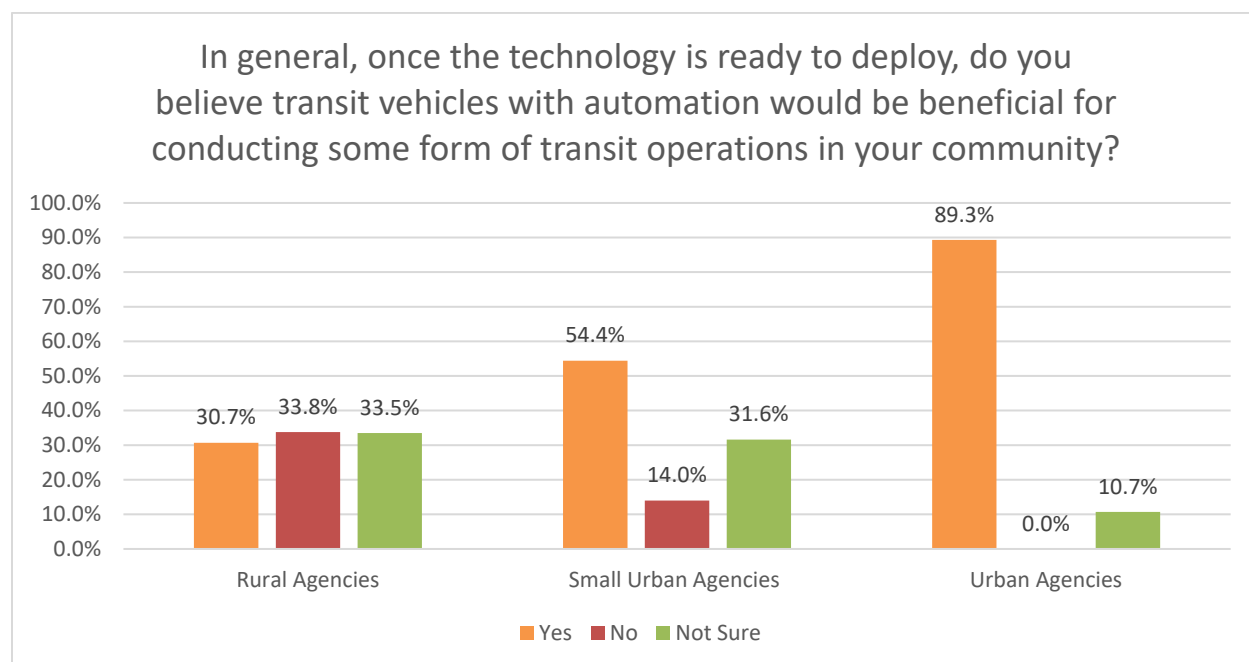

Figure 4.8 Benefit of Transit Automation in Conducting Some Form of Transit Operations

One of the top reasons rural, small-urban, and urban transit agencies believe that transit vehicles with automation functionalities would be beneficial for conducting some form of transit operations (once the technology is ready) is the potential for increased safety for bus operations. Features such as emergency braking, curb avoidance, narrow lane operations, advanced warnings/alerts (early detection systems of potential conflicts/accidents) to the operator for pedestrians, bicyclists, and other vehicles on the road could assist bus operators, as well as enhance safety.

Some specific reasons rural and small urban transit agencies believe transit automation technologies would be beneficial for conducting some form of transit operations include: 1) Transit agencies face challenges in finding qualified drivers; and automated transit vehicles could reduce the need for trained personnel. 2) Automated functions could help vehicles park closer to curbs, making it easier for riders to get on and off buses. 3) Automated transit vehicles have the potential to create more efficient and reliable service. 4) Automated transit vehicles have the potential to provide cost efficient services to people living in low-density and remote areas. 5) Automated transit vehicles have the potential to reduce transit operating costs.

Similarly, some specific reasons urban transit agencies believe transit vehicles with automated features would be beneficial are that they could maintain more efficient schedules, serve as efficient vehicles in sustainable transit systems, may be used in narrow lane operations, etc.

Transit agencies were asked which service/services they would choose if they had to introduce some level of automated fleet to their operations. Responses from rural, small-urban, and urban transit agencies are summarized in Figure 4.9. It can be observed from Figure 4.9 that except for rural transit agencies, most urban and small-urban transit agencies chose "traditional fixed-route service" for introducing some level of automation. As indicated in previous sections of this report, types of fixed-route transit services such as circulator and shuttle service seemed to be the most desirable options for incorporating fully automated shuttle services. Reasons for better applicability of transit automated technologies in fixed-route services include: 1) service being consistent, minimizing possible accidents, 2) stops located in fixed locations, making it easier to plan the service, 3) lanes could be narrowed for exclusive bus operations if needed, 4) buses could be operated without drivers to increase service levels, and 5) comparatively, the easiest service to automate. One reason most rural transit agencies preferred "demand-response service for general public" for introducing some level of automation instead of "traditional fixed-route service" is because most rural transit agencies do not operate fixed-route service.

Some of the specific types of services that transit agencies expressed interest in for experimenting with automated vehicle technologies include downtown circulators, hospital/university campus shuttles, airport shuttles, park and ride shuttles, etc.
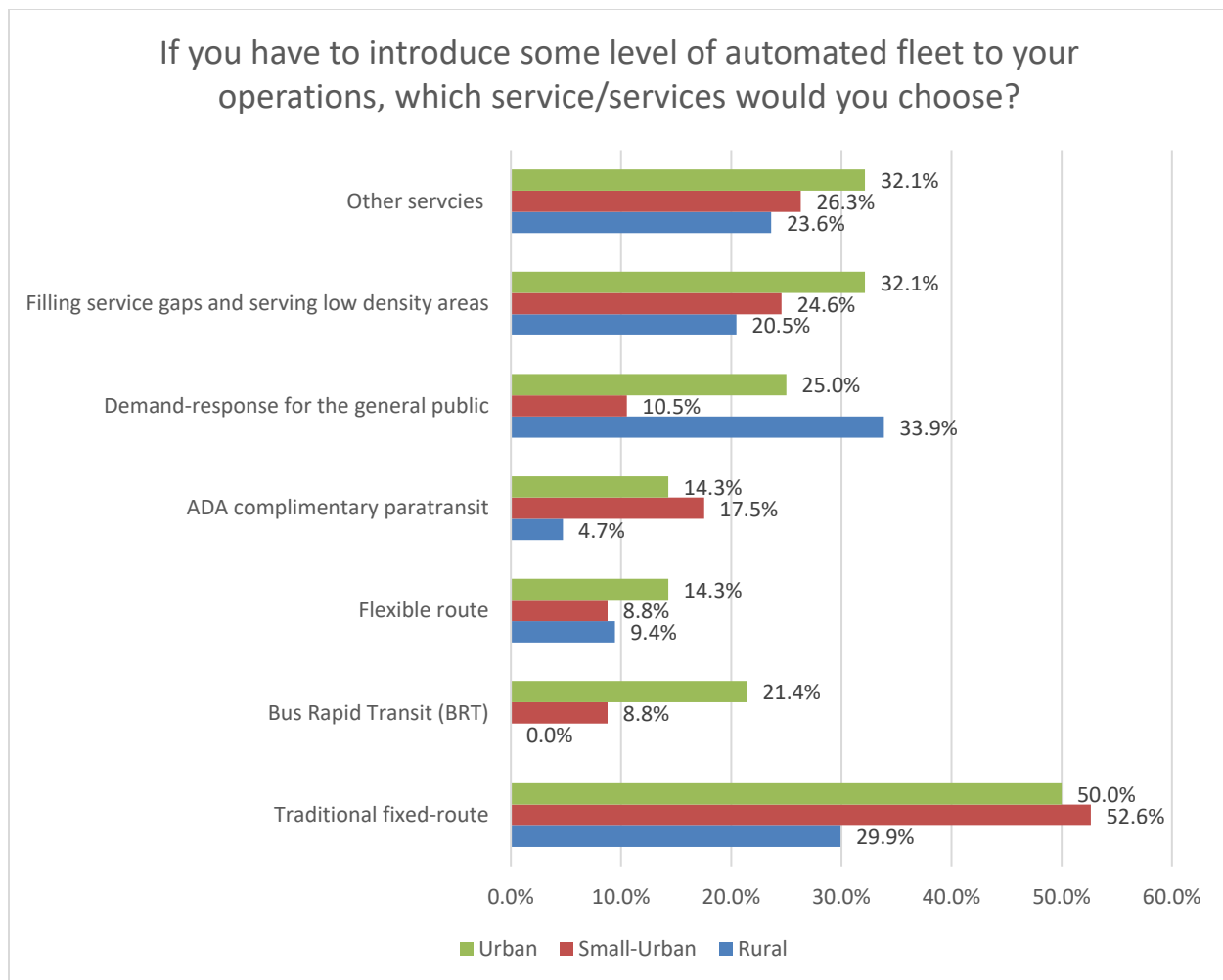
Figure 4.9 Preference of Service/Services for Introducing Some Level of Automated Fleet

4.4 Timeline and Procurement

The timeline for adopting various automation technologies such as precision docking, narrow lane/shoulder operations, lane-keep-assist, platooning transit vehicles automation, curb avoidance, collision avoidance, maintenance yard operations, and SAE Level 4/Level 5 vans/buses by transit agencies is summarized in Table 4.3.

While it is evident from the previous sections and from Table 4.3 that urban transit agencies are more proactive toward adopting these technologies, note that a significant percentage (although relatively low for a few technologies) of rural, small-urban, and urban transit agencies plan to adopt some form of transit automation technology in the next five years. The percentage of adoption increased among all transit agencies for a time frame of 5-10 years. Some of the technologies most favored for implementation in the near future by transit agencies include collision avoidance, curb avoidance, and lane-keep-assist. All of these technologies can be characterized as ADAS and have the potential to help the vehicle operator and enhance safety. While the rest of the automation features (narrow lane/shoulder operations, maintenance yard operations, SAE level 4 or 5 vans/buses, and precision docking) are not popular among most transit agencies, they did receive some interest among transit agencies that operate specific transit services that are not predominant among U.S. transit agencies. For example, agencies operating BRT systems could be interested in technologies for assisting with narrow lane/shoulder operations, platooning transit vehicles,

precision docking etc., Agencies providing circulator services, or campus/airport shuttle services may be interested in SAE level 4 or level 5 vans/buses such as low-speed automated shuttles. In general, as transit system size increases to include more urban agencies, demand for using various transit automation technologies was observed to increase.

Table 4.4 further summarizes the timeline for the procurement of transit vehicles with some level of automation and shows that few transit agencies have plans to procure these vehicles in next 2 years. A larger number of agencies would be interested in procuring these automated vehicles in 5 to 10 years.

Table 4.3 Timeline for Transit Agencies to use Various Transit Automation Technologies

Automation Technology	Rural Agencies		Small-Urban Agencies		Urban Agencies	
	next 5 yrs	5-10 yrs	next 5 yrs	5-10 yrs	next 5 yrs	5-10 yrs
Precision docking	11.4%	19.0%	14.9%	29.8%	10.7%	32.1%
Narrow lane/shoulder	12.6%	21.8%	16.3%	30.6%	17.8%	57.1%
Lane-keep-assist	29.7%	42.6%	34.6%	55.8%	53.6%	78.6%
Platooning transit vehiclesautomation	7.2%	14.4%	10.2%	18.4%	17.8%	39.0%
Curb avoidance	2.9%	43.6%	44.2%	63.5%	53.6%	75.0%
Collision avoidance	41.9%	51.4%	61.5%	65.4%	75.0%	85.7%
Maintenance yard operations	6.3%	11.4%	14.0%	16.0%	35.7%	46.4%
L4/L5 Vans/Busses	4.5%	10.2%	5.8%	11.7%	17.8%	42.8%

Table 4.4 Timeline for Procuring Transit Vehicle/Vehicles with Some Level of Automation

How soon do you think your agency will pursue procurement of transit vehicle/vehicles with some level of automation?	Rural Transit Agencies	Small Urban Transit Agencies	Urban Transit Agencies
In the next 2 years	2.5%	7.7%	18.5%
2-5 years	16.7%	17.3%	25.9%
5-10 years	22.5%	36.5%	37.0%
10-15 years	14.2%	21.2%	14.8%
>15 years	44.2%	17.3%	3.7%

Some potential challenges in procuring transit vehicles with some level of automation as identified by transit agencies include:
1. Funding for procuring these vehicles is the biggest hurdle. Because these vehicle technologies are in initial stages, the costs are very high and not affordable.
2. Public acceptance of the technology and public perception of safety of these technologies is low.
3. Reliability of the technology is a concern among transit agencies, local government, and the public.
4. Transit and local union officials may object to the adoption of automated technologies.
5. Hiring and training qualified operators and maintenance professionals will be difficult.
6. Fully ADA compliant vehicles are not available among the higher SAE level qualified transit vehicles.
7. Insurance and liability requirements are uncertain.
8. Existing transit fleet still has useful service life, preventing opportunities to explore and purchase new vehicles.

4.4.1   More Challenges for Small-Urban Transit Agencies

Additional challenges exclusively facing small-urban transit agencies in procuring transit vehicles with some level of automation to the fleet are:

1) Transit agencies are not willing to risk being early adopters of automated technologies, and cannot afford any fatal mistakes.

2) Transit agencies currently cannot fund basic transportation services and infrastructure in their communities, consequently advanced technology is out of reach.

4.4.2   More Challenges for Rural-Transit Agencies

Apart from all the above, challenges exclusively facing rural transit agencies that want to procure transit vehicles with some level of automation are:
1. Funding and vehicle procurement for rural transit agencies takes place through state agencies, so they cannot incorporate automated technologies unless state agencies are interested in these technologies.
2. Relevant technical capabilities (Wi-Fi, GPS, Cell Service, etc.,) required to accommodate automated technologies and transit services with these technologies is lacking in rural areas.
3. Infrastructure (such as curbs, lane markings, etc.,) to accommodate automated technologies for transit vehicles does not exist in rural communities.
4. Natural barriers such as rough mountainous terrain, adverse weather conditions such as snow, ice, etc. are more prevalent in rural areas.
5. Successful automated transit implementation examples are lacking in rural communities.
6. There are limiting options for operating demand-response types of services using automated technologies.
7. Older riders do not feel confident and safe with automated technologies.
8. Transit agency personnel lack knowledge about automated technologies and available vehicles with automation functionalities.

4.5   Needed Technical Assistance and Research

It is evident that some transit agencies are not fully aware of the potential for various transit technologies for conducting transit services. There is a need to provide information to transit agencies to educate them about various transit automation technologies and their potential for operations in various sized communities, and to provide updates on ongoing or successful implementation. Further, if an agency is planning to procure or has already procured vehicles with some automated features, technical assistance is important for help them understand the technology and conducting transit operations in an efficient and safe manner. Transit agencies were asked to choose what types of technical assistance are needed to guide them in the area of transit automation. Four options for technical assistance included topical webinars, example request for proposals (RFPs), face to face assistance, and a one-stop website of information. Transit agency responses with regard to needs for technical assistance are summarized in Figure 4.10. A significant percentage of rural, small-urban, and urban transit agencies indicated they needed all of the resource options. Apart from the four options provided, many transit agency respondents mentioned that site visits, gathering user experiences from other successful automated transit systems, and demonstrations at user conferences would help them learn about the potential of automation technologies and boost their confidence in potential implementation.
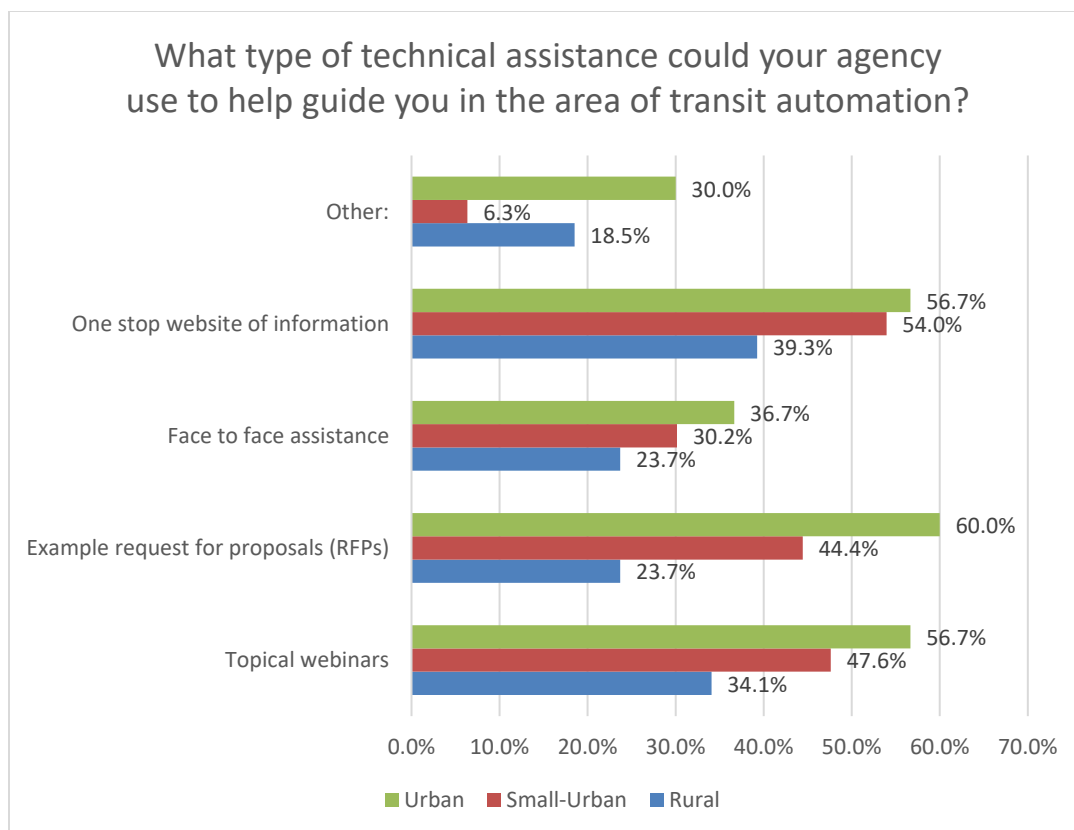
Figure 4.10 Technical Assistance Needed to Guide Transit Agencies in Transit Automation

Because automation in current transit operations is relatively new, there is a need for extensive research to assure these technologies are safe and reliable and that they will facilitate efficient transit operations. Reluctance to use these technologies immediately, or in the very near future can again be attributed to the fact that there has not been enough research and implementation, especially in smaller communities. Input was gathered from transit agencies about what areas of transit automation require additional research. Input is summarized in Figure 4.11. Safety was identified as the top topic for needed research in the context of transit automation technologies. Safety was also identified as the number one reason transit agencies are interested in transit automation technologies. Other areas of transit automation research of interest to transit agencies, in order of importance, include: capital and operating costs, cost effectiveness, human factors (users, operators), barriers (laws, regulations, policies) to transit automation, labor issues, policy, guidelines/standards, ADA operations, rural use, market analysis, and BRT. Research on rural use of transit automation technologies was mentioned as the number one area of research needed specifically by rural transit agencies.
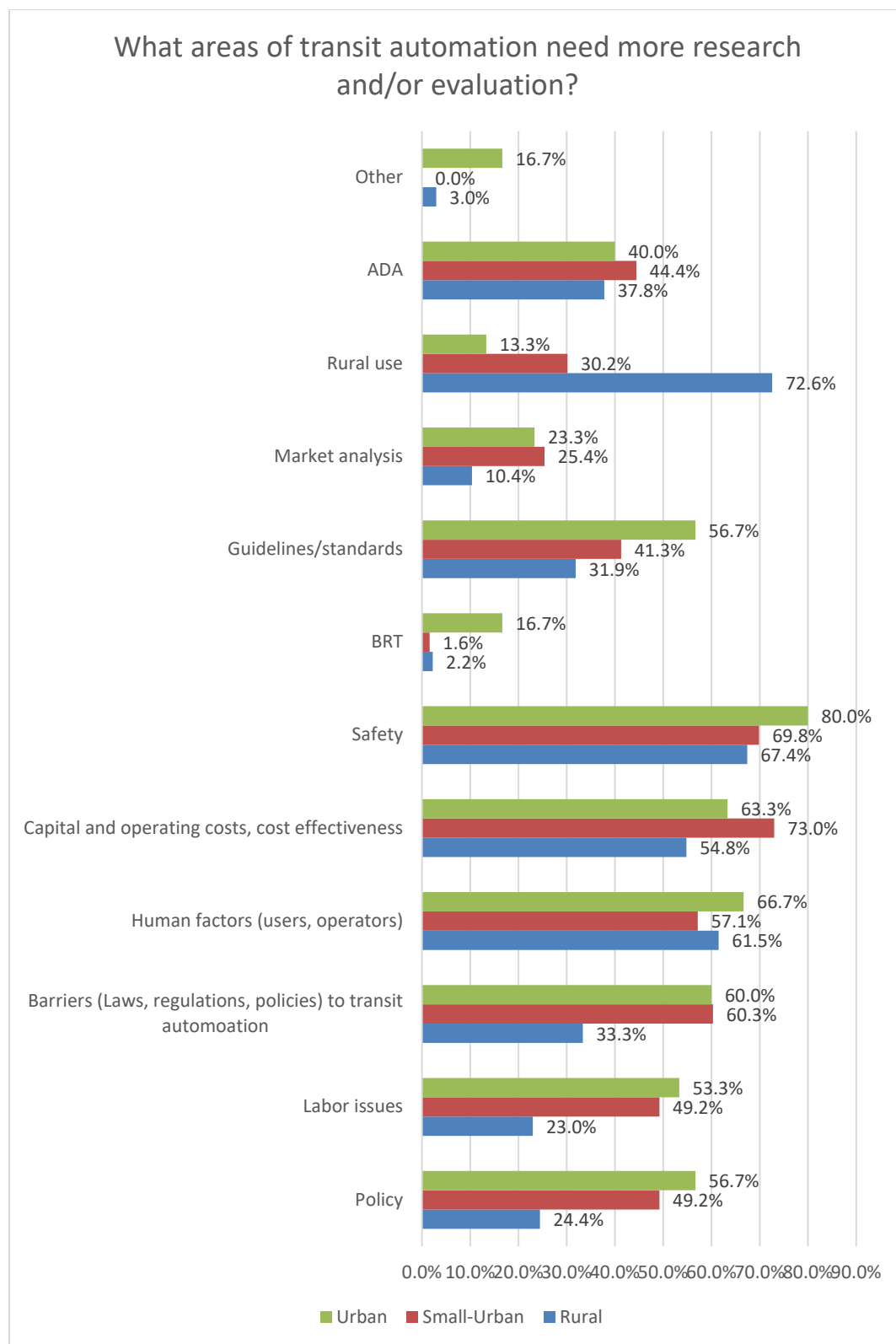
Figure 4.11 Research Needs in Transit Automation

4.6   Advantages and Concerns

Advantages and concerns for 'fixed-route service,' and 'paratransit and demand response service' are summarized below.

4.6.1   Fixed-Route Service

Advantages: Most common advantages of having transit fixed-route buses/vans/shuttles with some level of automated features (anywhere in Level 1-5) include:
1. enhance safety,
2. reduce/eliminate human error,
3. increase reliability of the service (on-time performance),
4. improve cost efficiency through reduced operating costs for level 4 and 5 vehicles,
5. increase service levels with level 4 and 5 vehicles,
6. overcome driver shortages with level 4 and 5 vehicles, and
7. enhance efficiency of operations with ADAS features such as narrow lane operations, curb avoidance, docking features, automatic braking etc.

While all various levels of transit automated technologies have the potential to enhance safety, some transit agencies are skeptical about the safety and security aspects of higher levels of automation (levels 4 and 5). In general, transit agencies believed that level 1-3 vehicles can improve safety, and level 4 and 5 vehicles could be cost efficient by reducing operator expenses and having the potential to operate throughout the day if needed for increased service levels. While level 4 and 5 do not need to have a driver, transit agencies feel that the vehicles would still need an operator/agent to provide focused customer support, as well as monitor the operating environment. Some of the selected comments from transit agencies expressing potential advantages are presented in Appendix C. It has been observed that a significant number of rural agencies are not sure, or are not knowledgeable about potential advantages of automation to fixed-route services.

Concerns: Most common concerns of having transit fixed-route buses/vans/shuttles with some level of automation features (anywhere in Level 1 -5) for potential operations include:
1. unproven record of safety,
2. high capital cost,
3. low public acceptance of the technology (driver acceptance, transit rider trust and acceptance, general public acceptance in the community),
4. labor union pushback with automated transit technologies,
5. lack of availability of qualified technicians to perform vehicle maintenance, service, troubleshooting, etc.,
6. lack of infrastructure (street design, transit dedicated lanes, etc.,) suitable for automated transit operations,
7. maintenance of roadway environment,
8. uncertainty of the reliability of technology,
9. job losses to transit automation technologies,
10. ADA compliance and passenger assistance on automated vehicles, especially for L4 and L5,
11. liability issues resulting from accidents,
12. L4 and L5 vehicles potentially unable to respond to sudden detours, road closures, etc.,
13. reliability of automated vehicle performance in winter weather,
14. technical glitches resulting in injuries, lawsuits, and other serious problems,
15. missing human element in the service, and
16. potential cybersecurity threats.

While there are not significant number of demonstrations of transit automated vehicles, and technologies in various sized of U.S. communities, there are many questions, suggestions, and concerns from transit agency respondents about ways the technology will be incorporated and their potential impacts. It is important to understand and properly implement the specific kind of automated technology that best fits a transit agency's service needs, and the community size to provide safe and efficient transit operations. Some of the selected comments from transit agencies with regard to the concerns listed previously are presented in Appendix C. Again, a significant number of rural agencies are not sure, or not knowledgeable about potential concerns of automation in transit fixed-route services.

4.6.2   ADA Paratransit and Demand-Response Service

Advantages: Most common advantages of having ADA paratransit and demand-response service vehicles with some level of automation features (anywhere in Level 1-5) for potential operations include: 1) enhanced safety and an ability to reach more people/expand service (DR service), and 3) reduced operational costs. Some of the selected comments from transit agencies with regard to these advantages are presented in Appendix C. It has been observed that a significant number of rural agencies are not sure, or not knowledgeable about potential advantages of automation to ADA paratransit and demand-response services.

Concerns: Most common concerns of having ADA paratransit and demand-response service vehicles with some level of automation features (anywhere in Level 1 -5) include: 1) safety, 2) lack of driver or person on board to assist passengers, 3) lack of funding, 4) lack of knowledge with vehicle maintenance and service, 5) uncertainty about applicability in rural areas, and 6) accommodation of wheelchair lifts/ and wheelchair restrain systems. Selected comments from transit agencies with regard to these concerns are presented in Appendix C. Again, a significant number of rural agencies are not sure, or not knowledgeable about potential concerns of automation to ADA paratransit and demand-response services.

5.   CONCLUSIONS

This study gathered input from U.S transit agencies in rural, small-urban, and urban areas. This input was used to understand transit agencies' interest in implementing various automated transit technologies, procurement and time line, and identify opportunities, challenges, and research needs.

Transit agencies believe transit vehicles with all SAE levels (1 to 5) can promote safety. However, because safety of higher levels of automated transit vehicles (4 and 5) has not been extensively researched in all sizes of communities and various types of environments, there are concerns and unanswered questions among some transit agency respondents about the technology's effectiveness, reliability, and performance. In general, transit agencies believed that transit vehicles in level 1-3 can improve safety, while vehicles in levels 4 and 5 could be cost efficient by reducing operator expenses and have the potential to operate throughout the day if needed for increased service levels. While levels 4 and 5 don't need to have a driver, transit agencies feel that the vehicles would still need an operator/agent to provide focused customer support and monitor the operating environment. The need for an operator or agent is observed to be much more important if level 4 or level 5 vehicles had to provide ADA paratransit, or demand-response type of services.

Most rural transit agencies have comparatively less awareness about the specifics of various transit automation technologies, and are not knowledgeable about potential advantages, concerns, and opportunities of automation features to their agencies. As transit agency system size increased to include more urban systems, awareness and demand for using various transit automation technologies was observed to increase.

Agencies that operated fixed-route services thought that "fixed-route service" would be a best-use case for deploying some level of automated technologies to their operations to help assist the driver with alerts/warnings and improve safety with features such as collision avoidance technologies, curb avoidance, lane keep assist, etc. Fully automated shuttles or transit vehicles in the SAE level 4 or 5 categories have some interest among transit agencies, preferably in simpler circulator routes with fewer conflicts. Examples may include downtown circulators, university shuttles, hospital campus shuttles, airport shuttles, parking shuttles, etc. Most transit agencies in smaller communities (rural and small-urban) are not interested in adopting fully automated shuttles or transit vehicles in SAE level 4 and 5 categories until they witness successful demonstrations of such services in similar sized communities.

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APPENDIX A: EXPERTS WHO SERVED AS SURVEY REVIEWERS

1. Chris Zeilinger, CTAA
2. Sean Peirce, John A. Volpe National Systems Center
3. Dennis Hinebaugh, CUTR
4. Robyn Kibler, CUTR
5. Nikhil Menon, CUTR
6. Paul Larrousse, NTA
7. Robert James, Intelligent Transportation Group

APPENDIX B: SURVEY INSTRUMENT FOR TRANSIT AGENCY SURVEYS

Survey with Transit Agencies: Use of Autonomous Vehicle Technologies for Conducting Transit Operations

Organization/Transit Agency Name:

Person Completing Survey:

Title:

City:

How do you categorize your transit agency?

○ Urban Transit Agency (Serving City or Metropolitan Area with Population > 200,000)

○ Small Urban Transit Agency (Serving City or Metropolitan Area Population in between 50,000 to 200,000)
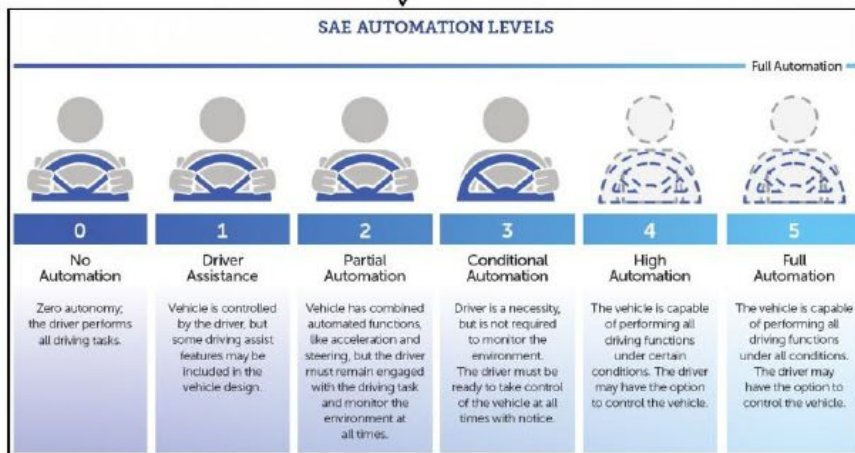
○ Rural Transit Agency (Serving City Population < 50,000)

What type of bus transportation services does your organization provide (check all that apply)?

☐ Traditional fixed-route

☐ Bus Rapid Transit (BRT)

☐ Flexible route

☐ ADA complementary paratransit

☐ Demand-response for the general public

☐ [   ] Other

Are you aware about the SAE Levels of Vehicle Automation?

○ Yes, I know them in detail

○ Yes, I know them briefly

○ No, I do not know them

Please review below SAE (initially established as Society of Automotive Engineers) Levels 1-5 of Vehicle Automation from National Highway Transportation Safety Administration's (NHTSA) most recent report 'Automated Driving Systems 2.0 A Vision for Safety'

					Full Automation
0	**1**	**2**	**3**	**4**	**5**
No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Are you familiar with the Federal Transit Administration's STAR (Strategic Transit Automation Research) Plan? (If not, please find below a brief description of FTA's STAR Plan)

○ Yes

○ No

STAR Plan: FTA has developed a five-year Strategic Transit Automation Research (STAR) Plan to support the development and deployment of automation technologies in bus transit operations in the United States. The STAR plan provides a five year roadmap which describes a set of research projects conducted, integrated demonstrations of automation technologies in bus operations, and strategic partnerships to advance the FTA's automation goals in bus transit operations. Please visit this web link for more information: https://www.transit.dot.gov/automation-research

Do you know about the Fully Autonomous shuttles (SAE Level 4, 5) used for circulator bus service, feeder bus service etc., (eg: Navya, EasyMile, etc.,) that are currently being operated in locations such as Las Vegas, NV and the University of Michigan Campus, Ann Arbor, MI?

○ Yes

○ No

Sample Fully Autonomous Shuttles that are currently operational in United States

Navya Autonomous Shuttle   EasyMile Autonomous Shuttle

Does your agency currently operate, or plan to operate in the near future fully autonomous shuttles similar to the vehicles shown above?

○ [   ] Yes; Please provide more details:

○ [   ] Maybe; Please provide more details:

○ [   ] No; Comment:

For which services do you think your agency could potentially use a Fully Autonomous shuttle (such as Navya or EasyMile) in your service area in the upcoming years? (Select all that apply)

☐ Traditional fixed-route

☐ Bus Rapid Transit

☐ Flexible route

☐ ADA complementary paratransit

☐ Demand-response for the general public

☐ [   ] Other; Please describe:

☐ None, we do not plan to use fully autonomous shuttles in the near future

Which other ways do you think a Fully Autonomous shuttle can be used for providing transportation services for your community ? (Select all that apply)

☐ Circulatory bus service

☐ Feeder bus service / first-mile last-mile shuttles

☐ Filling service gaps and serving low density areas

☐ Shuttles at airports

☐ Shuttles on university campus

☐ Shuttle service on hospital campus

☐ Shuttles on retirement communities/amusement parks/tech parks etc.

☐ Downtown or business park circulator

☐ [   ] Other; Please describe

In the future, similar to autonomous shuttles, fully autonomous buses will be available in various sizes (30 foot, 40 foot, articulated, etc.,). For what all services do you think your agency could potentially use autonomous buses of various sizes?

○ Traditional fixed-route

○ Bus Rapid Transit

○ Flexible route

○ ADA complementary paratransit

○ Demand-response for the general public

○ [   ] Other; Please describe:

○ None, we do not anticipate to use fully autonomous busses in the near future

Do you know about transit buses with Advanced Driver Assistance System (ADAS) (SAE Level 1-2) which have automation features such as narrow lane/shoulder operations, precision docking at BRT stops, platooning, curb object avoidance, automatic emergency braking (to include pedestrians), etc. etc.? (Please see below for brief description of each ADAS feature)

○ Yes

○ Yes, I learned about the transit buses with ADAS in detail for potential usage in our operations

○ Yes, we have transit bus/buses with some ADAS features in our fleet currently, or we are planning to have them in our fleet soon. Please [   ] mention the features:

○ No

Note: Brief explanation of each automation feature provided below:
Automation features in Narrow lane/ Shoulder: Advanced Driver Assist Systems used in bus transit operations, and BRT operations to operate effectively and safely in narrow lanes and/or shoulders.
Precision docking: Advanced Driver Assist Systems used for docking BRT vehicles close and consistently to the bus stations.
Platooning: The term "vehicle platooning," in its broadest sense, uses radar and vehicle-vehicle communications to form and maintain a close-headway formation between at least two in-lane
vehicles, controlling the vehicles both longitudinally and laterally at highway speeds, implying at least Level 2 automation.
Curb Avoidance and Automating Emergency Braking : Driver assist features in a bus (or transit vehicle) to avoid any maneuvers with curbs and sensing any obstacles/pedestrians for automatic emergency brake applications in a bus.

In general, once the technology is ready to deploy, do you believe transit vehicles with automation would be beneficial for conducting some form of transit operations in your community where you provide transit services?

○ [_____] Yes (Please tell us why?)

○ [_____] No (Please tell us why?)

○ [_____] Not sure (Please tell us why?)

If you have to introduce some level of automated fleet to your operations, which service/services would you choose? Select all that apply. Please also provide an explanation.

☐ [_____] Traditional fixed-route; reason:

☐ [_____] Bus Rapid Transit (BRT); reason:

☐ [_____] Flexible route; reason:

☐ [_____] ADA complementary paratransit; reason:

☐ Demand-response for the general public; reason:

[_____]

☐ Filling service gaps and serving low density areas; reason:

[_____]

☐ Other Service; Please describe and mention the reason:

[_____]

Which automation features do you think your transit agency will be using in the next **5 years**? Please select one response for each feature.

	Not Applicable	Very Unlikely	Unlikely	Not Sure	Likely	Very likely
Precision docking for transit buses.	○	○	○	○	○	○
Automation driving features for buses/transit vehicles in narrow lane/shoulder operations.	○	○	○	○	○	○
Lane keep assist systems.	○	○	○	○	○	○
Platooning of transit vehicles using automation.	○	○	○	○	○	○
Curb avoidance features.	○	○	○	○	○	○
Collision avoidance systems.	○	○	○	○	○	○
Maintenance yard operations.	○	○	○	○	○	○
Level 4/Level 5 autonomous vans or buses.	○	○	○	○	○	○

Which automation features do you think your transit agency will be using in the next **5-10 years**? Please select one response for each feature.

	Not Applicable	Very Unlikely	Unlikely	Not Sure	Likely	Very Likely
Precision docking for transit buses.	○	○	○	○	○	○
Automation driving features for buses/transit vehicles in narrow lane/shoulder operations.	○	○	○	○	○	○
Lane keep assist systems	○	○	○	○	○	○
Platooning of transit vehicles using automation.	○	○	○	○	○	○
Curb avoidance features.	○	○	○	○	○	○
Collision avoidance systems.	○	○	○	○	○	○
Maintenance yard operations.	○	○	○	○	○	○
Level 4/Level 5 autonomous vans or buses.	○	○	○	○	○	○

Which automation features do you think your transit agency will be using in the next **10-15 years**? Please select one response for each feature.

	Not Applicable	Very Unlikely	Unlikely	Not Sure	Likely	Very Likely
Precision docking for transit buses.	○	○	○	○	○	○
Automation driving features for buses/transit vehicles in narrow lane/shoulder operations.	○	○	○	○	○	○
Lane keep assist systems	○	○	○	○	○	○
Platooning of transit vehicles using automation.	○	○	○	○	○	○
Curb avoidance features.	○	○	○	○	○	○
Collision avoidance systems.	○	○	○	○	○	○
Maintenance yard operations.	○	○	○	○	○	○
Level 4/Level 5 autonomous vans or buses.	○	○	○	○	○	○

How soon do you think your agency would pursue procurement of transit vehicle/vehicles with some level of automation to your fleet of transit vehicles?

○ In the next 2 years
○ 2-5 years
○ 5-10 years
○ 10-15 years
○ >15 years

What are the potential challenges you could think of for procuring transit vehicles with some level of automation to your fleet?
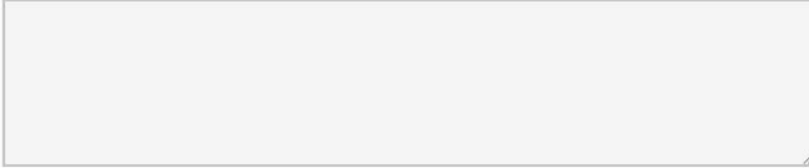
What type of technical assistance could your agency use to help guide you in the area of transit automation? (Check all that apply)

☐ Topical webinars
☐ Example Request for Proposals (RFPs)
☐ Face to face assistance
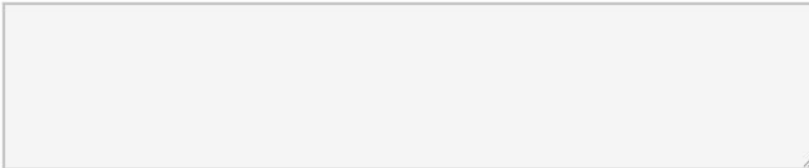☐ One stop website of information
☐ [   ] Other:

What areas of transit automation need more research and/or evaluation? Check your top 5 choices.

☐ Policy
☐ Labor issues
☐ Barriers (laws, regulations, policies) to transit automation
☐ Human factors (users, operators)
☐ Capital and operating costs, cost effectiveness
☐ Safety
☐ BRT
☐ Guidelines/standards
☐ Market analysis
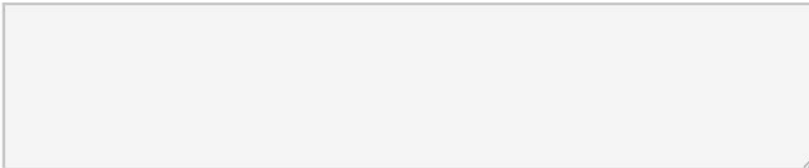☐ Rural use
☐ ADA
☐ [   ] Other

Could you mention some advantages of having transit fixed-route buses with some level of automation features (anywhere in Level 1-5) for potential operations in your service area? (If possible provide advantages separately for Level 1-3 and for Level 4&5.)
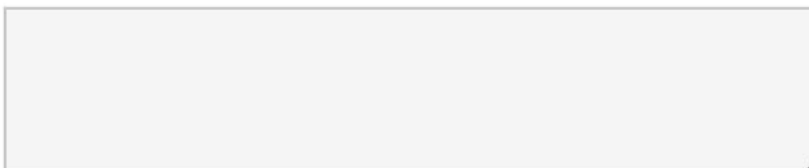
Could you mention your top two concerns (or more) of having transit fixed-route buses with some level of automation features (anywhere in Level 1-5) for potential operations in your service area? (If possible provide concerns separately for Level 1-3 and for Level 4&5.)

Could you mention some advantages of having ADA paratransit vehicles with some level of automation features (anywhere in Level 1-5) for potential operations in your service area? (If possible provide advantages separately for Level 1-3 and for Level 4&5.)

Could you mention your top two concerns (or more) of having ADA paratransit vehicles with some level of automation features (anywhere in Level 1-5) for potential operations in your service area? (If possible provide concerns separately for Level 1-3 and for Level 4&5.)

Could you mention some advantages of having Demand Response Service (non-ADA paratransit) vehicles with some level of automation features (anywhere in Level 1-5) for potential operations in your service area? (If possible provide advantages separately for Level 1-3 and for Level 4&5.)

Could you mention you top two concerns (or more) of having Demand Response Service (non-ADA paratransit) vehicles with some level of automation features (anywhere in Level 1-5) for potential operations in your service area? (If possible provide concerns separately for Level 1-3 and for Level 4&5.)

Please provide your contact details if you are willing to answer any follow-up questions.

Name:

Email:

Phone:

APPENDIX C: TRANSIT AGENCY SURVEY RESULTS

Table C1: Small-Urban Transit Agencies that Operate or Plan to Operate Fully Automated Shuttles (as of November 2018)

SN	Small-Urban Agencies	Details
1	Twin Cities Area Transportation Authority (TCATA), Benton Harbor	Not Provided

Table C2: Urban Transit Agencies that Operate or Plan to Operate Fully Automated Shuttles (as of November 2018)

SN	Urban Agencies	Details
1	Toledo Area Regional Transit Authority	Have grant to fund 3-year pilot system.
2	Roadrunner Shuttle, Camarillo, CA	Parent Company RATP Dev operates in another location that is currently testing and using Autonomous vehicles
3	Metropolitan Transit Authority of Harris County, Houston	Pilot project to operate either a Navya or EasyMile shuttle as a university circulator on the campus of Texas Southern University. Phase I (University operations) will begin in January 2019. Phase II which will connect to public transit at METRO's Light Rail Line 2 blocks away will begin in late FY19.

Fixed-Route Service – Selected Comments about Advantages
Survey Question: What are some advantages of having transit fixed-route buses with some level of automation features (anywhere in Level 1 -5) for potential operations in your service area? (If possible, provide advantages separately for level 1-3 and for level 4&5.)
"Fully automation (level 4 & 5) could potentially be a cost savings to the agency if results in a reduction in labor required to operate. Levels 1 through 3 features could provide for enhanced safety for the operation of the vehicles resulting in reduced liability costs."
"Lower level driver assist features are fine. I have significant concerns over level 4-5 automation due to ZERO ability to ensure systems are secure and cannot be hacked and people kept safe."
"Level 1-3 could improve driver safety because drivers can become distracted by events happening during their routes. Level 4 & 5 would drastically cut transit expenses because agencies wouldn't have to pay driver salaries or benefits."
"All levels enhance the degree of safety. Our campus area is extremely high in pedestrian and bicycle activity and so the more assistance our operators can have, the better."

Fixed-Route Service – Selected Comments about Concerns

Survey Question: What are your top two concerns (or more) of having transit fixed-route buses with some level of automation features (anywhere in level 1 -5) for potential operations in your service area? (If possible, provide concerns separately for level 1-3 and for level 4&5.)

"Street design / size here in town could be a challenge (not having transit dedicated lanes) - nor a culture of respect towards transit buses or any other bus (I.e. School Buses)."

"I do not foresee major concerns for early adoption of levels one through three for fixed-route operations. I think the higher levels 4 and 5 will face policy issues, acceptance by the general public, and resistance from drivers due to the loss of jobs."

"I have no concerns. This is an inevitable trend that needs to be embraced and planned for."

"The uncertainty of the reliability of the technology is the primary concern, particularly for levels 4 & 5."

"1 - I have concerns about ADA loading/unloading safely and them being secure onboard the bus. 2 - Potential traffic reroutes that happening instantly...due to road closures and accidents."

"Drivers relying too heavily on the technology and not their skills."

Demand-Response Service – Selected Comments about Advantages

Survey Question: What are some advantages of having demand response service (non-ADA paratransit) vehicles with some level of automation features (anywhere in level 1 -5) for potential operations in your service area? (If possible, provide advantages separately for level 1-3 and for level 4&5.)

"The advantages for non-ADA vehicles for levels 1-3 are primarily safety and operations through collision avoidance and docking, or other functions that assist the driver. For levels 4 and 5, safety should be a primary advantage that results in fewer accidents, lower insurance costs, and less operating costs if there is no need for a vehicle operator."

"Lower level driver assist features are fine. I have significant concerns over level 4-5 automation due to ZERO ability to ensure systems are secure and cannot be hacked and people kept safe."

"Level 4 or 5 could be very cost effective for low volume demand responsive service if it is reliable."

"Cost effective option to reach geographically isolated areas"

"Level 1-3: Increased safety; improved on-time performance.
Level 4-5: Reduced labor costs if driver is no longer necessary; increased safety and reduced incidents of crashes; better predictability of service for passengers, because automation demands consistency."

"We will be able to provide a number of rides to persons not currently accessing transit for convenience factors."

"We will not be using 3, 4 or 5. For 1 and 2, it would help drivers in areas that are unfamiliar to the driver. Would also help in areas where other motorists and pedestrians are not expecting to see a bus, so rapid response by the transit vehicle would improve safety."

"Easy on driver. The drivers provide control with passengers, who would do this. If passengers start arguing who steps in? My driver found a lady in the floor of her home yesterday when she didn't come out to get on the van, what happens now to these individuals?"

"Levels 1-5: Improved safety is the #1 advantage; while #2 would be the potential to improve/expand service."

Demand-Response Service – Selected Comments about Disadvantages

Survey Question: What are your top two concerns (or more) of having demand response service (non-ADA paratransit) vehicles with some level of automation features (anywhere in level 1 -5) for potential operations in your service area? (If possible, provide concerns separately for level 1-3 and for level 4&5.)

"Safety - how would it affect riders that need assistance to SAFELY board/de-board the vehicle and or to secure themselves.
Elderly population / passengers with cognitive challenges rely on the Operator for directions, remind them of their bus stop, etc."

"The need for passenger assistance that is more frequent in ADA paratransit operation, and the cost effectiveness in this type (demand-response) of deployment."

"I do not have concerns for levels 1-3. Higher levels such as level 4 and 5 will need time to address overall safety concerns and other technological improvements. Low-speed vehicles in exclusive right-of-way do not appear to have a very high risk, however, when operating in mixed-traffic at higher speeds, level 4 and 5 vehicles will have to become a proven technology before gaining widespread adoption. Other policy issues along this line will raise concerns as well."

"Possible safety of passengers on board if vehicle makes an abrupt maneuver while in operation."

"Lower level driver assist features are fine. I have significant concerns over level 4-5 automation due to ZERO ability to ensure systems are secure and cannot be hacked and people kept safe."

"Job security (3) is always a concern although I imagine it will be a long time until you won't need a person in the driver seat and we have achieved full automation without the requirement for a backup. I am also concerned when it comes to having automated vehicles sharing the road with regular citizens that are more likely to make mistakes (4). I am hopeful that there will be a reduction in accidents but there seems to be a different level of liability that needs to be taken into account."

"Level 1-3: increased cost per vehicle does not translate into significant improvement in service (on-time performance, etc.)

Level 4-5: fully-automated system is unable to respond nimbly to sudden detours, road closures, etc."