MODEL DEVELOPMENT FOR USER BEHAVIOR WHILE ADOPTING AUTONOMOUS VEHICLES AS THEIR ON-DEMAND TRANSPORTATION MODE

By

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DEDICATION

I dedicate this thesis to my beloved parents, Falguni Patel and Ketan Patel, who have been my source of inspiration and pillar of support.

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ABSTRACT

PREDICTIVE MODEL DEVELOPMENT FOR USER BEHAVIOR WHILE ADOPTING AUTONOMOUS VEHICLES AS THEIR ON-DEMAND TRANSPORTATION MODE

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Shared autonomous vehicles (SAVs) are a new technology that allows passengers to skip hailing a cab using a smartphone app to summon an autonomous shuttle that does not require a human operator. SAVs are anticipated to improve the efficiency, mobility, safety, and affordability of transportation systems. However, consumers will determine the success of SAV technology. Researchers have studied the associations between individuals' attitudes, preferences, and adoption of self-driving services focusing mainly on potential riders with no actual ridership experience. However, the literature lacks empirical assessments of riders' adoption and acceptance of SAVs. Therefore, this study aims to develop two models identifying the factors impacting: 1) users frequency of using SAVs; and 2) users and non-users willingness to use SAVs in the future.

The first model identifies the factors impacting the users frequency of using SAVs using structural equation modeling (SEM) based on data collected from a short ridership survey distributed among the users of a self-driving pilot project. Model 1 results indicated that race, trip purpose, waiting time, and the availability of a private vehicle significantly influence the frequency of using SAVs. The second model identifies the factors impacting the users and non-users willingness to ride the SAVs based on the data collected from a comprehensive survey distributed among users and non-users. Model 2 results suggested that the frequency of using SAVs directly impacts willingness to use SAVs, and sociodemographic attributes of the SAV riders indirectly

influence willingness to use SAVs through the mediators, including RAPID usage, existing modes of transportation, and vehicle ownership.

Moreover, this study aims to develop an ordinal logistics regression (OLR) model to analyze the impact of users and non-users attitudes towards SAVs on their willingness to use SAVs using the data from the comprehensive survey. The result from the OLR model indicated that ease of using SAVs positively impacts willingness to use SAVs in the future, and safety concerns about SAV technology negatively impact willingness to use SAVs in the future. This study also aims to provide in-depth insights into perceptions, attitudes, preferences, and concerns of users and non-users of the SAV technology using the qualitative data collected from focus groups and personal interviews. The content analysis of the focus group revealed that participants with visual impairment anticipated that future SAV services would enhance their mobility through advanced apps, booking systems, and vehicle equipment. The content analysis of interviews indicated that waiting time, pick-up and drop-off locations, and the ability to make tight turns at the intersection are the three major concerns related to SAVs. Moreover, potential riders anticipate that SAVs will be cost-efficient, environmentally friendly, and safer than human-operated vehicles.

This study provides crucial insights into individual travel behavior after integrating SAVs with existing transportation systems which will help local, state, and government transit agencies to develop policies and a transportation infrastructure that will enhance SAV operations universally. The findings of this study offer several implications for designing future SAV services in line with the needs of persons with disabilities. Moreover, this study provides insights into the perceptions and attitudes of SAV users and non-users and identifies strategies for successfully integrating an SAV service with an existing on-demand ridesharing service.

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CHAPTER 1

INTRODUCTION

1.1 Background

Technological advancements like smartphones and widespread data connectivity have given rise to an innovative transportation concept of mobility on-demand (MOD), allowing customers to book, call, or use shared and public transportation services using a single interface instead of privately owned vehicles (Shaheen, Cohen, & Martin, 2017). On-demand mobility services have emerged as a transportation mode that provides temporary access to vehicles for a short period (Shaheen & Bouzaghrane, 2019). Ridesharing (individuals with a common origin/destination or both share a vehicle), car-sharing (access to a shared vehicle for a limited time), ride-sourcing services (links drivers with passengers using smartphone application), and electronic hailing (E-Hail) (allows passengers to hail a taxi on-demand via a mobile application) are all examples of on-demand mobility (Greenblatt & Shaheen, 2015). According to researchers, the integration of autonomous vehicles with shared mobility technology would contribute significantly to attaining sustainable transportation.

Autonomous vehicles are new form of transportation that allows riders to get from one point to another without any human intervention (Manfreda et al., 2021). Autonomous vehicles have been broadly classified into six levels by the Society of Automotive Engineers (SAE) ranging from Level 0 to Level 5 (no automation to full automation) (Society of Automotive Engineers, 2021). Until recently, 35 states have passed legislation or issued executive orders relating to autonomous vehicle technology in the United States. (National Conference Of State Legislatures, 2021). In recent years 17 Level 4 SAV pilot projects have been deployed in 8 states throughout the United States (Stocker & Shaheen, 2019). These pilot projects were operating mainly under two scenarios 1) University Campus and Planned Communities and 2) Public Roads. However, about 53% of these pilots were in the testing phase with pre-selected passengers, and 47% provided a ride to the general public.

AV technology will transform the current transportation system (Zhang et al., 2015). Autonomous vehicles (AVs) will revolutionize transportation by enhancing traffic safety and quality of life . They have several benefits, including minimizing the need for parking spots in urban areas, increasing mobility for individuals with disabilities and those without licenses, and decreasing car accidents, traffic congestion, and fuel economy (Fagnant & Kockelman, 2015; Haboucha et al., 2017). According to researchers, autonomous vehicles will account for over 90% of the entire fleet by 2055, with AV technology likely to be operational by 2030 (Greenblatt & Shaheen, 2015). However, switching from conventional to automated transportation systems may present some difficulties (Hulse et al., 2018). Recent developments in AV technology can change how people travel by enabling them to migrate to suburbs and changing the layout of urban areas (Jing et al., 2020). Moody et al. (2020) indicated that individuals from poorer nations with severe road safety challenges are optimistic, while those from developed countries with more traffic and lower road mortalities are pessimistic about AV use and safety in coming years. Lavieri et al. (2017) believed that lifestyle factors might significantly impact the use of autonomous vehicles and suggested that young adults and those who are highly educated, tech-savvy, and/or urban residents are more inclined to adopt AVs than older and rural residents. Autonomous vehicles (AVs) are expected to play a crucial role in achieving sustainable transportation in the near future, making it essential to acquire insights into the public's acceptance of them so they can be successfully integrated into the existing infrastructure. Identifying factors affecting SAV adoption after their integration into existing transportation system will help transit agencies and policymakers to develop policies and a transportation infrastructure that will enhance future SAV operations.

1.2 Problem Statement

The challenges of understanding AV users' characteristics, users' travel patterns, and behavioral changes arise because fully autonomous vehicles have not yet been demonstrated on streets and highways (Kim et al., 2020). Previous research studied the public's opinion of AVs to better understand their preferences and concerns regarding the technology (Chikaraishi et al., 2020; Das et al., 2020; C. R. Hudson et al., 2019; Woldeamanuel & Nguyen, 2018; Xu & Fan, 2019), but because of the limited number of people with real-life experience in self-driving cars, they usually relied on data collected through surveys of potential consumers (Abraham et al., 2016; Asgari & Jin, 2019; Gurumurthy & Kockelman, 2020; Wu et al., 2020).

Moreover, past studies employed various methods and approaches to explore significant determinants of AV and SAV adoption. Wu et al. (2020) indicated that individuals were apprehensive about the safety and legal implications of AV technology. Zhang et al. (2015) used agent-based simulation and found SAVs reduce 90% of the parking demand of the individuals who use them. S. Wang et al. (2020) employed multinomial logit regression and discovered that early technology adopters had a positive outlook, but risk-averse individuals had a negative attitude toward AVs. Manfreda et al. (2021) used SEM and found that perceived safety and benefits can significantly influence the adoption of AVs while technological and legal barriers might negatively influence AV adoption. In addition, using SEM Yuen et al. (2021) demonstrated that perceived utility and accessibility significantly impact the behavioral intention to use AVs rather than income and education. However, even with simulations and consumer and preference surveys, it is difficult to truly understand the public's opinion of autonomous vehicles and impossible to predict how they will feel or what they will do in the future (Kim et al., 2020). Hence it is essential to identify the factors impacting SAV adoption and user travel behavior while adopting autonomous vehicles as on-demand transportation modes using data collected from real SAV ridership.

1.3 Research Objective

The objectives of this research are as follows:

1. To identify potential factors for successful integration of MOD service into current transportation infrastructure.

2. To identify individuals' perceptions, attitudes, preferences, and concerns towards SAVs after integrating into the existing on-demand ridesharing services using data collected from focus groups, one-on-one interviews, and surveys.

3. To develop a model to identify the factor impacting users frequency of using shared autonomous vehicles using data collected from distributing a brief survey to the users of an existing SAV service.

4. To develop a model to identify factors significantly impacting users and non-users' willingness to use SAVs in future using data collected from both the users and non-users of an existing SAV service.

1.4 Dissertation Layout

Chapter 1 consists of the research background, problem statement, and research objectives of this study. Chapter 2 presents a paper that describes an overview of the challenges and lessons learned during the implementation of the Federal Transit Administration (FTA) Sandbox Program projects. This paper also presents a list of potential factors to establish well-integrated MOD into current planning and modeling practices. Chapter 3 presents a paper that explores how people with disabilities perceive and accept autonomous vehicles (AVs) as a technology to improve their mobility. The results of this paper identify the factors (e.g. geographic accessibility, safety, technological advancement, and built environment) needed to be kept in mind while designing future AV services in line with the needs of persons with disabilities. Chapter 4 presents a paper that explores how riders use Shared Autonomous vehicles. The results of this paper identify the factors that influence how frequently riders take advantage of SAV services. Chapter 5 presents a paper that explores the factors affecting the users willingness to ride the SAVs based on the data collected from users and non-users of a shared autonomous vehicle (SAV) service. Chapter 6 presents a paper that explores the perceptions, attitudes, preferences, and concerns of users and non-users by sharing the results of qualitative data collected through personal interviews of users and non-users of an SAV pilot demonstration. Chapter 7 presents a paper that explores the perceptions, attitudes, preferences, and concerns of users and non-users by sharing the results of qualitative data collected through a focus group of users and non-users of an SAV pilot demonstration. Chapter 8 presents the conclusion, limitations, and recommendations for this study.

CHAPTER 2

MOBILITY-ON-DEMAND (MOD) PROJECTS: A STUDY OF THE BEST PRACTICES ADOPTED IN UNITED STATES

2.1 Abstract

The growth of mobility on demand (MOD) services has raised partnership opportunities between transit agencies and transportation network companies (TNCs) in the US. However, there is still a need to recognize how MOD programs confront different challenges during the implementation of pilot projects, and to what extent they are successful in promoting mobility efficiency and providing multiple mobility options. This study aims to evaluate the potential opportunities of public-private partnerships for MOD planning while presenting an overview of the challenges and lessons learned during the implementation of the Federal Transit Administration (FTA) Sandbox Program projects. Following a comprehensive review of MOD's background, we identify the goals and scopes of the 11 FTA Sandbox Program projects. The programs are classified into four categories: service to people with disabilities, first/last mile solutions, mobile application targeting one non-transit mode, and mobile application to integrate public and private transportation services on one app. Emphasizing particular FTA Sandbox Program projects, we determine the challenges and technical lessons learned during the implementation of the programs. Finally, this study identifies fundamental factors to a well-integrated public transit system that uses app-based on-demand technology. Our findings provide new insights, which could reinforce future partnerships among public-private transportation services.

Keywords: FTA sandbox program, mobility-on-demand, app-based on-demand services, transportation network companies (TNC)

2.2 Introduction

App-based on-demand ride services, commonly known as transportation network companies (TNCs), are rapidly growing private organizations using an online platform or mobile application to connect commuters with drivers operating their private vehicles (California Public Utility Commission, 2020). By 2017, a total of 10 TNCs (Uber, Fare, Fasten, Get Me, Tride, Liberty Mobility, Lyft, Ride Austin, Via, and Wingz) were operating in United States (Moran et al., 2017); Uber and Lyft are the most well-known of these. In 2019, about half of the U.S. population was aware of TNCs, and nearly 21% of adults in major US cities had used this type of service (Curtis et al., 2019). Accordingly, a new on-demand mobility service market has been established due to the introduction and popularity of TNCs.

MOD is defined as an innovative and emerging transportation concept in which transportation is considered as a good that can be supplied to consumers on-demand through different strategies. Mobility on-demand has evolved as a means of transportation that allows short-term access to automobiles through ridesharing (involves individuals with a common origin/destination perhaps both share a vehicle), car-sharing (provides access to a shared vehicle for a limited time), ride-sourcing services (connects drivers and passengers via smartphone application), and E-Hail (allows passengers to hail a taxi on-demand via a mobile application) (Greenblatt & Shaheen, 2015; Shaheen & Bouzaghrane, 2019). The technological advances in travel resulted in shaping MOD as a new concept including on-demand passenger and courier services, where consumers can access mobility via different modes such as TNCs, courier network services (CNS), ridesharing, bike-sharing, shuttle services, and microtransit (Shaheen et al., 2017a). MOD is suggested as a solution to improve mobility in low-density and suburban areas in which fixed-route transit is not as efficient as app-based services (Etminani-Ghasrodashti et al.

2021a, 2021b; Weinreich et al., 2020a). Atasoy et al. (2015) introduced the concept of flexible mobility of demand (FMOD), a transportation system consisting of vans offering multiple services like taxis, shared taxis, and minibus services depending on the transportation network demand.

Past studies have analyzed the impacts of using MOD as a substitute or feeder service for public transportation services as a first and last-mile solution. For instance, Ma (2017) developed a routing algorithm to ensure lower cost and seamless connections between multimodal trips by establishing a real-time dispatching policy for ridesharing services in conjunction with public transportation services and testing it based on the Luxembourg city transportation network. Moreover, researchers have also modeled the impacts of autonomous mobility of demand services using agent-based simulations. Shen et al. (2017) used agent-based modeling to study the impacts of autonomous mobility on demand (AMOD) service integrated with public transit systems to improve first and last-mile connectivity. The outcome of these studies suggested that multimodal ridesharing is financially viable and reduces the fleet size and waiting time.

Oh et al. (2020) identified the impact of AMOD service using agent-based simulation, collecting data through a stated preference survey in Singapore. Their results indicated that unregulated AMOD services significantly increase traffic congestion and vehicle kilometers/miles traveled. Similarly, simulating the impacts of the AMOD system in Zurich, Switzerland, Hörl et al. (2021) indicated that using a single passenger AMOD system will increase the distance traveled by vehicles. Y. Liu et al. (2019) developed a theoretical framework using Bayesian optimization to evaluate the impacts of MOD services on public transit systems through data collected from a stated preference survey in New York City.

Mobility features such as travel time, travel cost, flexibility, and reliability of the trips are the determinant factors that influence the demand for different transportation modes (Arif Khan et al., 2021a; Etminani-Ghasrodashti et al., 2022b, 2022c; Khan et al., 2022b; Shaheen & Cohen, 2020). In recent years, transit agencies have begun partnering with the TNCs to explore mutual advantages in mobility (Moran et al., 2017). In some U.S. states, in which Texas municipalities are taking the lead, the transit agencies and municipalities have employed the technology used by the TNCs to provide publicly subsidized transit service (Weinreich et al. 2020a). Utilizing innovative technologies, public transit agencies are able to partner with mobility on demand (MOD) companies to promote the efficiency and quality of the public transport services, particularly for the low-income, elderly, people with disabilities, and residents of distant and rural areas. Public transit TNCs are distinguishable from services like Uber and Lyft by using public subsidies to ensure low and consistent fares and by their use as either a complement to or substitute for traditional fixed-route services (Feigon & Murphy, 2016).

It has been observed that the new forms of public-private partnership for the provision of mobility through technology-enabled services can reduce car ownership and transportation costs, and boost the use of public transit (Feigon & Murphy, 2016). Chan & Shaheen (2012) discussed the importance of shared mobility (carsharing, bikesharing, on-demand ridesharing, and microtransit) in making the first/last mile connection with public transit. The primary motivation behind transit agencies' partnership with MOD companies is to increase cost-effectiveness and provide more mobility options for existing and future transit users (Curtis et al., 2019). Several measurable advantages of the partnership with MOD companies have been recognized, such as decreasing travel time and commute-related stress, reducing the overcrowding on high-ridership routes by providing first/last mile trips (Chan & Shaheen, 2012), lessening congestion mitigation (Santi et al., 2014), diminishing travel costs, and improving accessibility through subsidized trips (Lazarus et al., 2018). However, there are still some opposing views on the advantages and effectiveness of MOD services, including the concern that TNCs may reduce traditional public transit use (Hampshire et al., 2017; Rayle et al., 2016). Hence, transit agencies should thoughtfully implement public-private partnerships to restrict the competition with fixed-route public transit (Lucken et al., 2019).

To meet consumers, service providers, and partners' needs, Shaheen et al. (2020) identify four core enablers for MOD services, including business models and partnerships, infrastructure, policies and regulations, and emerging technology. Accordingly, they illustrate six types of partnerships between public transportation and MOD service providers, including (1) trip planning and fare integration, (2) first and last mile, (3) low-density service and public transit replacement, (4) off-Peak service, (5) paratransit, and (6) guaranteed ride home (GRH) (Shaheen & Cohen, 2020). Other scholars have studied MOD public-private partnerships in the United States and categorized four typologies of partnerships, including first/last mile, low density, off-peak, and paratransit (Lucken et al., 2019). Other common partnerships between public agencies with mobility service providers can include data sharing, risk sharing, integration with third-party apps, rights-of-way access, and management (Shaheen et al., 2020).

According to the MOD stakeholders' perspectives, the challenges and opportunities for public-private partnership are identified in four main areas, including (1) managing and understanding pilot data; (2) equity and accessibility; (3) economic impacts and innovative business models; and (4) planning for MOD (Shaheen et al., 2018; Shaheen et al., 2017b) (Shaheen, 2017b; Shaheen et al., 2018). While the benefits and issues of MOD varies for different stakeholders, the potential opportunities and equity challenges for consumers are of great interest (Shaheen et al., 2020). Tsay et al. (2016) suggest that transit agencies' partnership with MODs can improve the public transit options for consumers through four strategies: partnering to reinforce transit's strengths, leveraging agency-controlled assets, planning for a streamlined user experience, and being open to new ways of providing useful transit. Since safety, affordability, reliability and availability to all (e.g., people with disabilities, older adults) are the key performance indicators for MODs, factors such as data sharing, data accessibility, and data integration are reported as the solutions to the success of the program (Shaheen et al., 2019). However, the success of public-private partnerships to advance MOD cannot be the same in different land use contexts. Although dense areas have a tremendous potential to implement a successful MOD service, rural and suburban places may face more challenges resulting from physical and social isolation, such as poor cellular data access (Shaheen et al., 2017b).

One of the most effective efforts in improving mobility accessibility through innovative MOD and public transit partnerships is FTA's MOD Sandbox program. This program aims to integrate MOD solutions and benefits into transit services while utilizing technological advances. The MOD Sandbox seeks innovative approaches to provide a multimodal, integrated, automated, accessible, and connected transportation system through public-private partnerships (Federal Transit Administration, 2018). FTA's Research, Development, Demonstration, and Deployment program authority allocated a total grant of $8 million in 2016 for the 11 MOD Sandbox projects under Public Transportation Innovation (49 U.S.C. § 5312).

Although several qualitative reports reviewed and examined the literature of partnerships between public agencies and MOD companies, only a few academic studies have evaluated some of the FTA Sandbox case studies (Shaheen & Cohen, 2020). MOD Sandbox projects are evaluated through performance measures by the project partners; however, independent researchers have also the opportunity to explore the project efforts. While the academic literature in TNCs and MOD services is quickly evolving, little effort has been made to evaluate the success of the MOD Sandbox projects. In this paper, we study the FTA Sandbox program to evaluate the implementation of MOD projects in terms of opportunities and challenges for public transportation related to technology-enabled mobility services. Accordingly, this study aims to 1) identify the current MOD practices in the United States and evaluate the policies and procedures of MOD Sandbox Program projects, 2) explore the challenges and opportunities learned from the MOD Sandbox Program, and 3) determine factors that contribute to the integration of well-established public transit systems using app-based, on-demand services. Evaluating the Sandbox Program can provide new insights into the opportunities and challenges that different case studies have experienced through their on-demand mobility pilot programs. This study seeks to fill an existing literature gap and improve knowledge by evaluating the lessons learned in different MOD case studies and identifying the potential and actual challenges and opportunities related to deployed projects. The findings of this study will help local, state, and government transit agencies to assess and improve their existing policies to support the adoption of MOD services by the transit sector. Moreover, other private shared mobility providers could also get valuable insights on MOD practices adopted by transit agencies to integrate MOD services in the transit sector.

2.3 Methodological Approach

The FTA developed its MOD initiative to encourage an automated, accessible, multimodal, and connected transportation system that prioritized personal mobility (Federal Transit Administration, 2018). In 2016, to promote MOD projects, FTA started its Sandbox Demonstration Program by funding 11 projects to explore partnerships, integrate transit with MOD solutions, measure impacts, develop and validate new MOD business models, and identify government guidelines and policies that might bolster or hinder the acceptance of MOD by the transit sector. All 11 projects can be broadly divided into a variety of concepts and categories. A recent study by Shaheen & Cohen (2020) classifies the 11 MOD Sandbox demonstration pilots conceptually into the following four categories: smartphone applications and trip planners, integrated fare payment, first-and-last mile connections to public transportation, and paratransit. We developed our study based on a four-step approach, shown in Figure 2-1.

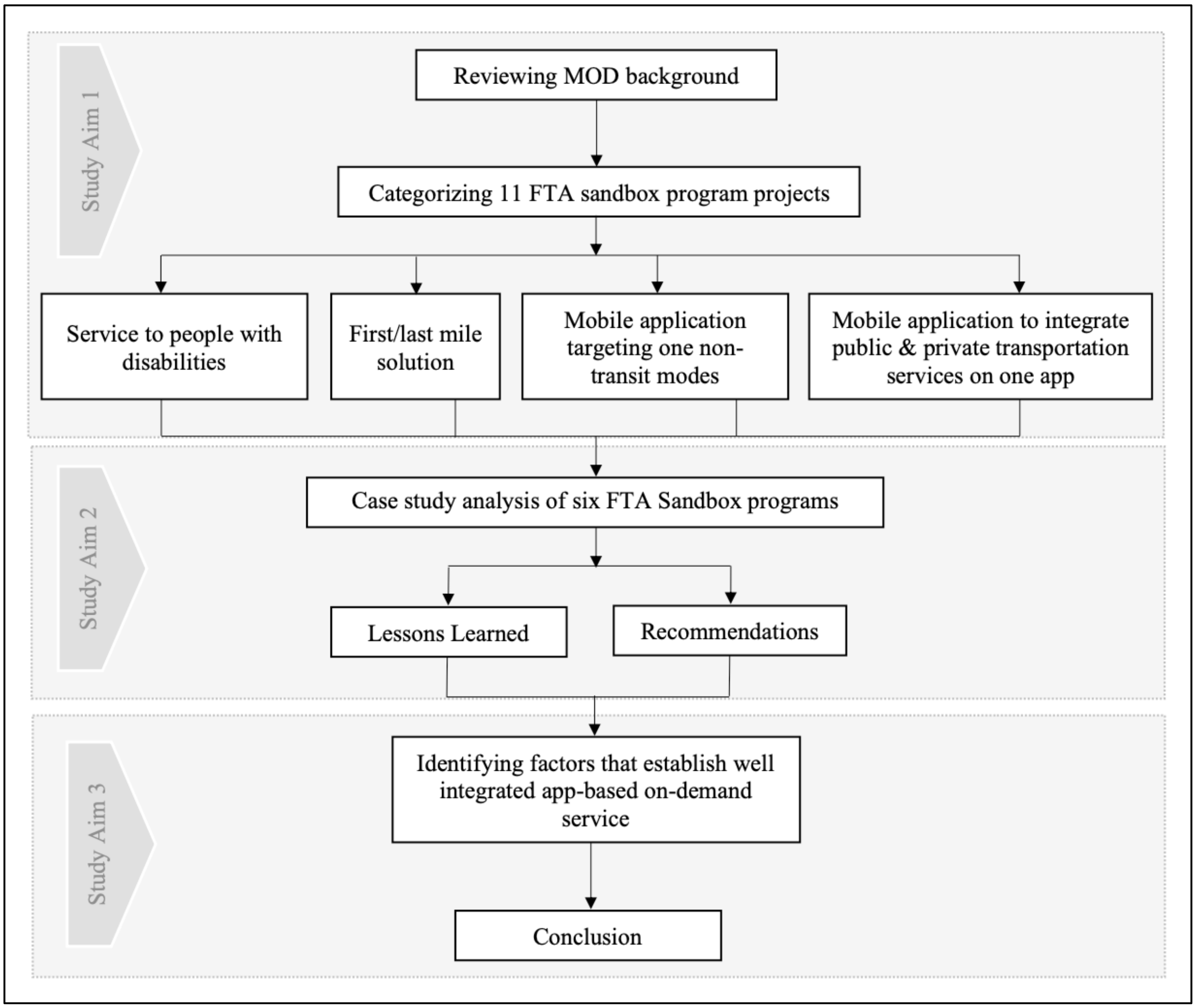

Figure 2-1 Research Methodology

At first, we reviewed the existing literature of "MOD" to evaluate the current practices in the United States. Second, we categorized the MOD Sandbox pilots based on the project scopes and goals into the four main categories: service to people with disabilities, first/last mile solutions, mobile application targeting one non-transit mode, and mobile application to integrate public and private transportation services on one app. Third, we narrowed our focus to six projects with at-least one project from all four categories mentioned above. Finally, we analyzed these projects to identify the challenges faced and technical lessons learned during implementation. Finally, we determined factors that assist with establishing a well-integrated public transit system using app-based on-demand technology.

2.3 Case Study Analysis

This section evaluates the 11 FTA Sandbox Program projects and identifies their project scope, goals, and key partners. Then, we categorize these 11 pilot projects into four categories, as shown in Table 2.1. Furthermore, we select six pilot projects from the total 11 pilot projects to explore the lessons learned and recommendations provided through the programs.

2.3.1 FTA MOD Sandbox Program Projects

2.3.1.1 Valley Metro Mobility Platform

This project was planned as a partnership between Lyft, Route Match, West Group & City of Phoenix. This MOD sandbox project was intended to integrate the payment option for private and public transportation services through a pilot application called “Pass2Go Pilot”. This application allowed riders to choose travel itineraries based on travel time, mobility preference, trip cost estimates, and proximity to transit options. The main goal of the project was to reduce the travel time (wait time and trip planning time) through application improvements. Toward the integration of fare payment options, this pilot project enhanced trip planning methods for people with disabilities (Cordahi et al., 2018a).

2.3.1.2 Regional Transportation Authority (RTA) of Pima County Adaptive Mobility with Reliability and Efficiency (AMORE)

In this project public and private transportation services were integrated in a single application to promote public transit ridership in the greater Rita Ranch area. The initial mobility modes combined on one platform would be driving (via personal vehicle), carpooling (via MetropiaDuo), transit hailing (Ruby Ride), and public transit (via fixed-route services, including app-based). As a partnership between MetropiaDuo & Ruby Ride, the project aimed to increase accessibility to different mobility options for older adults and people with no access to vehicles (Cordahi et al., 2018b)

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2.3.1.3 Pinellas Suncoast Transit Authority (PSTA)-Public-Private-Partnership for Paratransit Mobility on Demand Demonstration (P4MOD)

The project offered more efficient and economical on-demand, door-to-door paratransit service. This MOD Sandbox utilized new TNC technology and was a partnership among Lyft, Center for Urban Transport Research (CUTR) & Goin' Software, United Taxi, CarRide, and Wheelchair Transport. This project aimed to improve the mobility, accessibility, and quality of life of paratransit users within the county by reducing travel cost and travel time (Cordahi et al., 2018c).

2.3.1.4 Pierce Transit (PT) Limited Access Connection

This project was a partnership among Pierce College Puyallup, Sound Transit, and Lyft. As a first/last mile solution, this project was designed to provide mobility for riders needing transportation to and from selected zones and after the transit service has stopped at night. It also offered trips to and from park and ride lots and Sound Transit Stations to reduce congestion. The primary objectives of the project were improving access to Pierce transit bus routes, increasing transit ridership, reducing demand for parking, and providing access to paratransit services more cost-effectively (Cordahi et al., 2018d).

2.3.1.5 Los Angeles County and Puget Sound MOD First and Last Mile Partnership with Via Project

This project was a partnership between LAMetro, KCM, ST, and Via to develop, deploy, and analyze two pilot projects in Los Angeles County, CA, and King County, WA. This pilot program was designed to test the partnership between transit agencies and a TNC (Via) to provide equitable first/last mile transit access to their fixed-route networks. Improving mobility, accessibility, and reducing congestion from personal vehicles were the primary goals of the project. This MOD Sandbox project aimed to increase public transit's overall ridership by providing First Mile/Last-Mile (FMLM) and door-to-door late-night services solutions (Cordahi et al., 2018i).

2.3.1.6 Dallas Area Rapid Transit (DART) First and Last Mile Solution

The DART first and last mile solution provided seamless access to multiple transportation options by leveraging the GoPass ticketing app. This MOD Sandbox project was planned to implement soft integration of smart app platforms for TNCs (e.g., Uber and Lyft) and other MOD providers like carpool services and bike-share programs. This project benefits from a comprehensive partnership among technology partners (UnWire, Double Map, PayNearMe), carpool solutions (SpareLabs), taxi solutions (Irving Holdings), and TNCs (Uber and Lyft). The chief goals of the project were defined as increasing transit ridership within the pilot region, improving first and last-mile access to DART transit, enhancing access to multimodal travel options within the pilot region, and replacing ineffective fixed-route services in low-density areas with MOD services (Cordahi et al., 2018e).

2.3.1.7 Tri County Metropolitan (TriMet) Transportation District of Oregon OpenTripPlanner Shared-Use Mobility (OTP SUM)

This project aimed to create a mobile and desktop software platform to integrate transit and shared-use mobility options for customers to enable informed decisions for mobility choices, including first/last mile transit trips. The project planned to provide OTP and SUM users with real-time information regarding their trip plans and travel options to get to their destinations quickly. This pilot project was a partnership among Conveyal, IBI Group, Cleared for Takeoff, Moovel, Oregon Metro, and other contributing partners (Cordahi et al., 2018j).

2.3.1.8 Chicago Transit Authority (CTA) Integrated Transit Fare Systems from Transit Fare to Bike Share Project

This project was launched by CTA to allow customers easily access Divvy Bike, used by riders in downtown and other neighborhoods. The project aimed to increase awareness for Divvy Bikes among Chicago transit users, enable users to pay for bike-sharing using the Ventra App, increase bike sharing usage by transit users going to/from CTA and Metra Systems, and provide real time information regarding the status of the Divvy Bikes. CTA proposed two phases for the project. Phase 1 of the project would incorporate the location and status of Divvy Bike into the Ventra app so customers can get real-time information about the availability of their bike at the transit station and docking station. Phase 2 of the project planned to further integrate Divvy functionality into the Ventra app by including payment options (Ventra Transit Value), permitting customers to pay for the bike. This MOD Sandbox was a partnership among the Chicago Department of Transportation (CDOT), Cubic & Divvy (Cordahi et al., 2018f).

2.3.1.9 Bay Area Rapid Transit (BART) Integrated Carpool to Transit Access Project

This project intended to provide carpool travelers with a consistent method to pay for parking spots at BART stations through better coordination. Accordingly, this pilot project aimed to reduce the rate of fraudulent use of carpool space, increase the occupancy rate of vehicles parked at BART stations, and finally, raise total carpooling to BART stations. The key partners of the project included the Metropolitan Transportation Commission (MTC) and Scoop Technologies, Inc. (Cordahi et al., 2018g).

2.3.1.10 City of Palo Alto and Prospect Silicon Valley Bay Area Fair Value Commuting (FVC) Demonstration

The demonstration concentrated on decreasing Single Occupancy Vehicle (SOV) drive share by 25% through Fair Value Commuting (FVC) arrangements in Bay Area. The project generated a feebate or cash-out system that charges SOV commuters and pays non-SOV commuters. The project aimed to reduce the SOV fossil fuel consumption among employers to benefit lower income workers over the higher income population. Public and private agencies such as Prospect Silicon Valley, City of Mountain View, City of Menlo Park, RideAmigos, SPUR, and other potential vendors and pilot partners were reported as the project partners (Cordahi et al., 2018k).

2.3.1.11 Vermont Agency of Transportation (VTrans) Open Trip Planner

This project was a partnership between Cambridge Systematics and Trillium Solutions, Inc. The project aimed to develop a mobile or desktop-accessible open trip planner application, which provides access to flexible mobility options. By developing an online trip planner for both fixed and flexible service, this MOD sandbox would improve public transit use in Vermont and decrease call/response time inquiries related to route info and travel options (Cordahi et al., 2018h).

2.3.2 Categorizing the MOD Sandbox pilots based on the project scopes and goals

After analyzing the scope, goals, and stakeholders of the MOD Sandbox Program projects, we classified them into four main categories: For instance, (I) service to people with disabilities, (II) first/last mile solutions, (III) mobile application targeting one non-transit mode, and (IV) mobile application to integrate public and private transportation services on one app as shown in Table 2-1. Some projects did not exclusively focus on one particular category and were related to more than one category. For instance, the Valley metro mobility platform focused on enhancing service to people with disabilities and developing a mobile application to integrate payment systems for public and private transportation options. The Pierce transit limited access connection project focused on providing service to people with disabilities and first and last-mile coverage to people in need when the transit system stops providing services. Similarly, DART first and last-mile solution and TriMet OTP SUM project focused on integrating multiple shared-use mobility platforms into one mobile application to provide first/last mile access.

Table 2-1 Categorizing the FTA MOD Sandbox Program Projects

#	FTA MOD Sandbox Program Projects	Location	Stakeholders	I	II	III	IV
1	Valley Metro Mobility Platform Project	AZ	Lyft, Route Match, West Group & City of Phoenix	✓			✓
2	Regional Transportation Authority (RTA) of Pima County Adaptive Mobility with Reliability and Efficiency (AMORE) Project	AZ	MetropiaDuo & RubyRide	✓			✓
3	Pinellas Suncoast Transit Authority (PSTA) - Public-Private-Partnership for Paratransit Mobility on Demand Demonstration (P4MOD)	FL	Lyft, United Taxi, CarRide, Wheelchair Transport, Center for Urban Transport	✓			

			Research & Goin' Software				
4	Pierce Transit (PT) Limited Access Connection	WA	Pierce College Puyallup, Sound transit & Lyft	✓	✓		
5	Los Angeles County and Puget Sound MOD First and Last Mile Partnership with Via	CA	LAMetro, Kings County Metro, Sound Transit, & Via		✓		
6	Dallas Area Rapid Transit (DART) First and Last Mile Solution	TX	UnWire, Double Map, PayNearMe, SpareLabs, Irving Holdings, Uber & Lyft		✓		✓
7	Tri County Metropolitan (TriMet) Transportation District of Oregon OpenTripPlanner Shared-Use Mobility (OTP SUM)	OR	Conveyal, IBI Group, Cleared for Takeoff, Moovel, & Oregon Metro		✓		✓
8	Chicago Transit Authority (CTA) Integrated Transit Fare Systems from Transit Fare to Bike Share Project	IL	Chicago Department of Transportation (CDOT), Cubic & Divvy			✓	✓
9	Bay Area rapid Transit (BART) Integrated Carpool to Transit Access Program	CA	Metropolitan Transportation Commission (MTC) & Scoop Technologies, Inc. (Scoop)			✓	
10	City of Palo Alto and Prospect Silicon Valley Bay Area Fair Value Commuting (FVC) Demonstration Project	CA	Prospect Silicon Valley, City of Mountain View, City of Menlo Park, RideAmigos, & SPUR			✓	
11	Vermont Agency of Transportation (VTrans) Open Trip Planner	VT	Cambridge Systematics & Trillium Solutions, Inc.				✓

Note: **(I)** Service to People with Disabilities; **(II)** First/Last Mile Solutions; **(III)** Mobile Application Targeting One Non-Transit Mode; (**IV**) Mobile Application to Integrate Public and Private Transportation Services on One App

2.3.3 Findings: Lessons Learned from Six FTA MOD Sandbox Case Studies

In this section, we deeply evaluate six case studies from the 11 MOD Sandbox projects to determine the challenges and opportunities these pilot projects have confronted since their deployment. Identifying the lessons learned from MOD successes and failures can shed light on MOD solutions for all stakeholders, including cities, counties, regional agencies, mobility services, employers, and public transit.

2.3.3.1 Pierce Transit (PT) Limited Access Connection

In May 2018, as a part of the FTA's MOD Sandbox Program grant, Pierce Transit (PT) was awarded a grant of $205,299 to roll out its Pierce Transit Limited Access Connection pilot program. The project sought to provide mobility connection through three approaches: First, by providing a subsidized first/last mile service through collaboration with a rideshare partner in select areas; second, through a guaranteed ride home after service has stopped for the night; and third, by providing trips from park-and-ride lots and Sound Transit stations to reduce congestion (Cordahi et al., 2018d). While the project did not initially generate a high number of trips compared to others in the region, outcomes of this project indicated a steady increase in trips as well as public acceptance over time, as people became more familiar with the service and the technology (Grellier, Personal Communication, 2020).

Pierce Transit (PT) encountered serious limitations in gaining access to personally identifiable rider data based on its partnership with a private contractor for the operation of the service and the booking app. Without data from its TNC partners, the agency only had data for the small number of riders who booked through their phone option rather than the app. Since most trips were booked through the Lyft app (as the operation partner) using promo codes, the contact information of about 95% of program customers was not available. The promo codes to access rides were published in public marketing material, so there was no need for the customers to subscribe to the service or provide their contact information. PT managed to get feedback from the customers who opted for the call-in option, but those riders made up fewer than 5% of the total customers. Designing the service was also a significant challenge, as it was intended to attract new customers. Accordingly, extra time was needed for customers to learn about the service and adapt to use it. Identifying a successful service area was another challenge the PT project encountered. PT analyzed population density and previously existing fixed-route services to establish the need for the app-based, on-demand service.

Furthermore, it was supplemented by a license plate study of park-and-ride cars at transit stations to identify customer origins. Analysts also looked at walkability, access to fixed-route services, and the potential for congestion relief. Finally, PT looked for important destinations not being served by previously existing transit services, such as a community college with limited transit but heavily congested student parking facilities (Grellier, Personal Communication, 2020). To gain better insights into the PT project, we contacted the program manager through email. We gathered valuable information about the challenges, lessons learned, and recommendations made during the project, as discussed in the section below.

Lessons Learned and Recommendations

- The project was launched in May 2018, but it was not until March 2019 that a consistent number of trips were being taken by users. Hence, it is recommended that the length of a similar pilot project should be at least two years.
- Regular communication with private partners is essential. This project's outcomes show the necessity of holding a consistent standing call with private TNC providers, along with frequent technical queries.

- Various marketing approaches were adopted, ranging from traditional brochures and mailings to social media campaigns. Interestingly, more expensive advertisements on YouTube and Pandora were less effective (based on online engagement) than $200 spent on geofenced Facebook ads. Accordingly, continuous promotional marketing throughout the term of the pilot seems to be a more efficient approach of marketing.
- The pilot project also covered the entire cost of trips taken in the designated zones. This caused challenges to the agency because they were not privy to the inner workings of the TNC's pricing algorithms, which calculate those prices. For example, surge pricing, availability of drivers, and a myriad of other factor could impact price, but PT was unsure by how much and under what circumstances. As a result, the cost of a trip to the nearest transit connection point was unknown to the agency, though they had committed to paying the cost.
- According to project outcomes, one advantage of working with TNCs was their flexibility and eagerness to test new service approaches. For example, when PT decided to make changes to its service to check if shared-only rides could work in one of the zones, their TNC partner tested it out using Geofencing and modifications in their app.

2.3.3.2 Dallas Area Rapid Transit (DART) First and Last Mile Solution

The Dallas Area Rapid Transit's (DART's) First and Last Mile Solution Project received a $1.5 million grant in October 2016 and became a member of FTA's Mobility on Demand (MOD) Sandbox Demonstration Program. Although high-frequency rail and bus services were available in the Dallas Fort-Worth region, it was difficult for many of the residents to complete the first and last mile of their trip. About 24% of the jobs in the administrative area of DART and 28% of all residents in DART's service area live about a quarter-mile away from a bus stop or railway station (Cordahi et al., 2018e).

The Dallas public transit system did not have an app-based scheduling service and relied on the telephone or dispatch center to schedule services. To fill this gap, DART developed an application to provide its users with multiple on-demand traveling options to get them from a pick-up location to their destination, linking them with both government and private MOD providers in the area (Parks et al., 2020). As part of the demonstration program, they sought to upgrade the mobile application by providing travel information for multimodal trips, enabling unified payment systems, and collecting riders' data in a single, integrated trip booking system (Parks et al., 2020).

The goal was also to offer mobility-on-demand solutions that were accessible to disabled, unbanked, low-income, and smartphone-challenged customers (Weinreich et al., 2020b). By booking trips through the DART mobile app, DART controlled the fundamental information required for the National Transit Database (NDT) and provided extra safety to its customers by conducting background checks on its drivers and providing them better training than other private mobility-on-demand providers (Parks et al., 2020). DART created an account-based fare payment system for its GoPass app, for enabling multiple third-party transactions. As a result, DART's customers are able to leverage various payment options such as cash loading through PayNearMe integration, debit cards, credit cards, internet payment services, and other payment options that are provided for its unbanked customers.

DART undertook a one-year initial assessment of the advanced mobile application and its unified fare payment structure (Parks et al., 2020) through its GoLink project, an on-demand personalized curb to curb service. Two locations were discussed for the implementation of the GoLink project: Inland Port and Plano. Plano was selected as the initial GoLink location based on three criteria: the absence of a DART fixed route service, the density of the employee base, and access to a freeway (Parks et al., 2020). DART commenced its first GoLink on-demand service in the Legacy West area in October 2017. Routing algorithms, software deployment, and tablet hardware proved to be some of the major challenges in the pilot project (Parks et al., 2020). After the success of the initial service in March 2018, DART extended the operation to the far North Plano GoLink Zone in August 2018 (Parks et al., 2020).

DART conducted a self-evaluation of the performance of the MOD Sandbox Project, using the evaluation framework jointly developed by DART and the independent evaluation team of the US Department of Transportation (Cordahi et al., 2018e). Activity data was gathered from its GoLink service platforms (Tapride & Spare) and two surveys were conducted in three Plano zones to measure the success of the project. The survey results and analysis of the activity data gathered from the Tapride and Spare platforms suggested that DART had accomplished a considerable part of its objectives by growing ridership, decreasing the cost for each traveler, extending the area served, and enhancing customer satisfaction of both general ridership and disabled customers (Parks et al., 2020). Nevertheless, according to DART's final report to the FTA (Parks et al., 2020), the project confronted several difficulties and provided useful lessons for other transit agencies developing MOD apps and first/last mile services, described below.

Lessons Learned and Recommendations

- Reliable software is a very crucial part of a MOD's operational success. It needs to be transparent for the driver, reservation employees, and dispatchers, and include features that can help resolve complaints. DART developed a Standard Operating Procedure that included mandates such as making sure that the devices used for the driver application are compatible with the MOD service and surroundings, checking the voltage required for charging devices to ensure that they are fully charged during the service hours, and acquiring extra charged devices in case of failures during the service hours.

- Some drivers reported trip sequence issues due to technology limitations; therefore, DART made it mandatory for dispatchers and reservationists to accompany the drivers on trips to understand the issues that they faced.
- While the software was only designed for streamlining on-demand service, DART also allowed pre-scheduled rides and walk-on riders to use their service. This was presumably to increase access for riders without cell phones or bank accounts, though the report does not clarify this point. While this helped ensure equitable access, it also required the driver to physically enter, in real time, the information of riders that walked onto the vehicle without a reservation. This often led to a delayed arrival at the next location and compromised the efficiency of the software.
- DART has been proactive in resolving existing issues and preparing for potential ones to help their passengers acclimate to their technology. For instance, they provided fare discounts to new app users to promote the use of their latest technology. When they found that trip sequence was insufficient for understanding the technology restrictions, their impact on the system and users, and the issues that the drivers faced, they mandated that reservationists and dispatchers ride alongside them. They understood the importance of providing their customers, particularly those with limited access to technology, with support that is appropriate for their situation to facilitate adoption of their technology. For example, transit agencies should provide alternatives to riders without internet access and credit cards, as they are unable to use services such as smartphone apps and mobile

ticketing. DART's customers, via the GoPass app, can leverage multiple payment options like Apple Pay, cash-to-mobile, and GoPass Wallet for using transit services.

2.3.3.3 City of Palo Alto and Prospect Silicon Valley Bay Area Fair Value Commuting (FVC) Demonstration Project

Fair Value Commuting (FVC) project operated in the Silicon Valley suburban areas that have experienced a tremendous amount of economic growth but are faced with increased traffic congestion and distortions. In 2016, the City of Palo Alto was awarded a $1,085,000 grant from the FTA MOD Sandbox program to demonstrate FVC. FVC was designed to decrease the Bay Area single occupancy vehicle (SOV) commute share of employees in general through the implementation of its five components, including:

1- ECTR (Enterprise Commute Trip Reduction) Software: A platform integrating employer human resources and payroll functions and distributing benefits such as loading Clipper transit fare cards and allowing pre-tax purchase of transit passes, while collecting and reporting commuter mode choices.

2- Commuter Wallet: A mobile multimodal trip planning platform developed with a seamless combination of public/private transit and employer incentives.

3- Feebate/Cashout: Charges a fee for SOV commutes and rebates that revenue to non-SOV commutes.

4- Gap Filling: Identify commutes with poor alternatives and subsequently attempts to improve them.

5- Systemic Obstacles: Enabling better public transit routes and integrating transportation payment systems.

Accordingly, FVC aimed to decrease SOV car trips, increase public transit ridership and the perception of public transit, and create a sustainable mechanism for funding new transit, biking, carpool, and mobility services. The Commuter Wallet successfully integrated with the project's ECTR vendor, through supporting a path toward real-time, intermodal trip planning and payment methods. The outcomes from FVC also revealed a reduction in SOV car trips, VMT, and fossil fuel use. Evaluation of the project outcomes indicated that during the six months of pilot, participating employees logged 4,918 alternative trips, traveled 84,072 non-SOV miles, burned 502,365 calories, saved 41,186 pounds of CO_2, and saved $21,046 in avoided auto-related travel expenses (Rupert, 2020). According to the final report submitted to the FTA (Rupert, 2020), the project faced various challenges and provided valuable lessons learned during the project, as discussed below.

Lessons Learned and Recommendations

- FVC started with several challenges with the public-private partnerships, indicating the importance of managing expectations of all project partners.
- FVC was not able to establish a feebate mechanism for using parking revenues to fund non-SOV. The project outcomes demonstrated that getting public as well as private sector employers to disregard parking as a benefit is not easy.
- FVC indicated that technology was essential in supporting the program platforms. Offering a good graphical interface and a good personal dashboard with metrics for alternative trips, alternative miles, CO2 emissions reduced, and money saved were recognized as the most important features that encouraged employees to engage with these two platforms, and plan and pay their trips with alternative modes. The integration of different platforms in one project increased the ability for platforms to be complementary.

2.3.3.4 Vermont Agency of Transportation (VTrans) Open Trip Planner

Transportation software tools should be able to provide the users of rural and distant areas with information about demand-responsive trips similar to that available to fixed-route transit providers using the General Transit Feed Specification (GTFS). GTFS is defined as "a data specification that allows public transit agencies to publish their transit data in a format that can be consumed by a wide variety of software applications" (Rask et al., 1994). The Vermont Agency of Transportation (VTrans) Go! Vermont Trip Planner Project, introduced in February 2018, is a good example of using GTFS data. As a part of its Sandbox Program grant of $480,000, it provides users with information about all the public transit services in the state of Vermont, making multimodal journeys a viable transit solution, even in rural regions without fixed route networks. The new features included Dial-a-Ride, Hail and Ride, and deviated fixed services, all especially common in rural areas not adequately served by other trip planning technologies (MacDonald, 2020).

To demonstrate how a software application could potentially provide users with information about demand-responsive trips, the VTrans project included the development of a software application ready to ingest and use GTFS-flex. OpenTripPlanner (OTP) provided the right platform to implement the demonstration of GTFS-flex trip planning because it already used GTFS data, and the open-source nature of the project allowed VTrans free access to design a project, using the code without limitations on approaches or license fees (MacDonald, 2020). VTrans (MacDonald, 2020) provided valuable lessons they learned throughout this project in a report to FTA, as discussed below.

Lessons Learned and Recommendations

- The Go! Vermont trip planner still lacks some major features that the users need, the primary one being real-time information on flexible transit service in Vermont.
- Go! Vermont provides an easy way for riders to discover the transit services that will enable them to reach key destinations, but without real-time information, riders must plan trips a day or more in advance.
- The GTFS-booking specification extension, or a similar transactional standard, could provide information about services available in the very near term (next few minutes or hours) through an application programming interface (API).
- The entire trip reservation process could be performed through the GTFS-booking extension, along with user interface advancements to OTP and other apps.
- Real-time information is of no use, however, if the booking process continues to require a phone or interaction with a system outside the trip planner. This presents inherent challenges for transit agencies seeking to make the process more equitable for riders without access to smart phones and bank accounts, and riders with disabilities, who may require a telephone booking process.

2.3.3.5 Valley Metro Mobility Platform Project

In January 2017, Valley Metro decided to develop its new mobility platform “Pass2Go” as a part of its FTA sandbox demonstration grant of 1 million dollars. The project aimed to build trip planning features that did not exist in its previous trip planning application, “RidekickTM,” and integrated payment for multiple transportation options in the area. In the past, people needed to check various applications to look up transportation options within the region (Martin et al., 2020a). The project had two phases: Phase 1 included developing a trip planner with travel information for all the public and private transportation options and an integrated payment system; Phase 2 included integrating private ridesharing companies like Uber and Lyft. However, Phase 2 was not completed due to challenges faced while combining private ridesharing companies within a mobile app (Martin et al., 2020a).

The platform was evaluated three times every three months from March 2018 to September 2018 to check its efficacy. The users had to complete a pre- and post-survey while using the app four times per month for three months. Apart from the survey, three other data sets, Pass2Go Pilot app data, Payment Data, and Stakeholder Interviews, were used to evaluate the hypothesis developed in the evaluation plan. The evaluation results suggest that there was significant decrease in wait time and planning time in bus and rail trips for the Pass2Go Pilot app users. Additionally, there was a significant increase in the frequency of use of certain public transportation services (Valley Metro Rail, Valley Metro Bus) and the modes of transportation connecting these public transport services (Taxi, Bike Sharing, Uber and Lyft, Walking, Bicycle) (Martin et al., 2020a).

One of the challenges faced by Valley Metro during the planning process was that its Chief Technology Officer (CTO) and Routematch (the project's software developer) were overly optimistic about the timeline to roll out the mobile application without considering the institutional process and understanding the app development cycle. Another challenge for Valley Metro was integrating private TNCs into its application. Attorneys of the private TNC partner (Lyft) had data concerns due to Arizona's "Sunshine Law," which requires a private business to disclose all records except for personally identifiable information. Additionally, Lyft expressed concerns related to user experience outside their app. Although Valley Metro tried to overcome these challenges by creating a relationship between Routematch and Lyft, the integration did not move forward within the project (Martin et al., 2020a). We have listed the lessons learned throughout the project in the following section, considering the final report (Martin et al., 2020a) submitted to FTA.

Lessons Learned and Recommendations

- Valley Metro wanted to target the periodic users who use daily passes rather than the regular users with monthly passes to get feedback on the pilot project. As a result, they hired a local market research firm West Group, which had an existing relationship with the agency to help them recruit participants and develop strategies to incentivize providing feedback. West Group linked its project management software with Routematch through an API, enabling them to get user information, which allowed them to obtain critical pilot information from before and after surveys through targeted marketing, considered one of the best practices for encouraging user engagement and app usage.
- Valley Metro carried out internal and external stakeholders training by developing training modules for their staff to get familiar with the app on different devices. However, they found difficulties with the third-party contractors as their operators could not identify the transit passes.
- It was difficult for Valley Metro to find a third-party app developer to overcome digital accessibility challenges. However, they hired a third-party web developer for the demonstration to improve digital accessibility and comply with the World Content Accessibility Guidelines (WCAG). Consequently, Valley Metro believed that the accessibility test resulted in a much-improved user experience.
- According to Valley Metro, it is important to have an inhouse developer to represent the agency and translate their needs to the vendor whenever they outsource work to a third-

party developer. The in-house developer can also provide online app support to customers who have technical concerns and challenges.

2.3.3.6 Tri County Metropolitan (TriMet) Transportation District of Oregon OpenTripPlanner Shared-Use Mobility (OTP SUM)

TriMet initiated its MOD sandbox demonstration TriMet Open Trip Planner (OTP) Shared-Use Mobility (SUM) in January 2017 as a part of its $678,000 grant to create an open-source platform integrating public transit with SUM options like bike share and TNCs. The user interface was responsive to mobile and web platforms, helping users make informed mobility choices for first and last-mile trips. TriMet wanted to change its OTP code base with its MOD demonstration to integrate public transit using SUM modes with real-time information and implement a fully functional open geocoder built upon the existing Pelias geocoder. In addition to making changes to the core framework, the project also included developing a comprehensive web-based user interface that allows users to do intermodal trip planning and improves base map data for better location search and geocoding (Martin et al., 2020b).

Lessons Learned and Recommendations

- According to project stakeholders, regular coordinated communications with online project management platforms (such as Slack, Trello, etc.) in the form of in-person meetings and workgroup sessions were critical for deciding a clear timeline for the project deliverables keeping the project on track.
- Project stakeholders suggested that the TriMet MOD sandbox demonstration allowed the regional transportation agencies to get unified on data standards and data sharing, giving them the ability to negotiate with the private TNCs operating on the national level. TriMet

emphasized building trust and long-term relationships with all the project partners and spurred on other MOD stakeholders to follow it.

2.3.4 Comparing Performance Factors of Six FTA MOD Sandbox Case Studies

To evaluate the level of success of each Sandbox program, multiple performance metrics were used by independent evaluation teams. Performance metrics represent the measures used to identify each specified MOD project's impacts and evaluate the project-specific goals. The most usual performance metrics applied in the six above mentioned MOD Sandbox projects are as follows:

- Ridership changes as a result of the app development, such as ridesharing and public transit ridership, as a result of app and travel mode development
- Accessibility and mobility
- Wait times, travel times, trip planning times
- Distance of travel by automobiles
- Users' perceptions of service performance towards mobility, accessibility, and connectivity
- Cost per rider
- Customer satisfaction
- Number of general public trips arranged using scheduled demand response trips
- Number of active users
- Number of multimodal trips

To identify the key factors that resulted in the success of each MOD program, this study first reviewed the performance metrics identified through the independent evaluation process and compared the metrics between different projects. Due to the conflicting goals and priorities affecting the evaluation of these services, it was not possible to provide one comprehensive list of performance metrics usable for comparing the success of all programs. For instance, Pierce Transit (PT) Limited Access Connection's primary goal was to improve the mobility of the underserved population in lower-density areas through increasing connectivity to existing bus routes outside of regular service hours and by the collaboration of NTC agencies (Grellier, 2020). The DART project centered on the same goal but by improving FMLM access to transit through microtransit mode (Martin et al. 2021b). The primary focus of the FVC project was reducing SOV car trips, shifting to transit modes by developing a universal software for trip planning and payment (Rupert 2020). Similarly, VTrans aimed to improve mobility for Vermont transit riders via enhancing trip data presentation for transit riders (Martin et al. 2021a). Designing more precise goals, the Valley Metro Sandbox project aimed to decrease the riders' travel time and waiting time by improving the adoption of mobile-based technology for trip planning (Martin et al. 2020a). Finally, increasing access to real-time information to improve comprehensive trip planning was the main goal of the OTP SUM project (McHugh et al., 2021).

Accordingly, we compared the same metrics that could have a vital role in the performance of each Sandbox program. These metrics include the amount of the grant assigned to the project, the average trip cost per ride, the length of the service demonstration, the total number of trips for programs that provided transportation service, the number of queries and transactions for trip planning programs, and the percent of low-income service users (see Figure 2-2).

DART First and Last Mile Solution MOD Sandbox Demonstration had the most funding and has offered the highest rate of total traveled trips by the GoLink system during its 13 months of pilot deployment. This project has the lowest trip cost where riders could pay $1.50 to travel to or from any destination within a single zone. However, results of the February 2019 survey of DART GoLink shuttle users indicate that only 31% of the respondents were low-income riders with a gross household income of less than $35,000. Since the DART GoLink service was primarily designed to provide service in low-density suburbs, most early service users were from higher-income regions. Accordingly, to replace the service with fixed-route transit in more urban and lower-income neighborhoods, DART added additional service areas in both Plano and Southern Dallas (Martin et al. 2021b).

The average trip cost for Pierce Transit (PT) Limited Access Connection was among the highest. However, it is assumed to be more cost-efficient than the previous fixed-route transit demonstrations in the area. Nevertheless, about 67% of PT users were estimated to be from low-income households with annual incomes of less than $35,000 (Grellier 2020).

The FVC Demonstration Project has the lowest length of demonstration. However, over about a six-month FVC pilot, 56 participants engaged in the program and recorded about 4918 alternative non-SOV trips. This population was roughly 23% of the 240 low-income commuters who were offered transit subsidies through this program (Rupert 2020).

Evaluation of the web traffic data related to Go! Vermont trip planner indicated that actual users attracted to the trip planner had at least ten queries per day (around 3900 total queries in 13 months). In addition, the Go! Vermont user survey reported that about 22% of users were from lower-income classes with approximately $35,000 to $50,000 in gross household income (Martin et al. 2021a).

For a flat rate of $4 per pass, the Valley Metro Mobility Platform Project had an average sales per user of $78 and a total sale of $48,956 during 21 months of the deployment. Analyzing the Pass2Go app showed 12,239 transactions for 626 users from March 2018 through November

2019. A self-reported survey of 307 Pass2Go Pilot users revealed that about 44% of the respondents had a gross household income of less than $ 35,000 (Martin et al. 2020a).

OTP SUM has the longest project timeline compared to other pilot projects. According to the OpenTripPlanner survey, almost 21% of the users reported an income of less than $25,000 per year. To identify the multimodal functionalities of evaluating the time/cost trade-off between transit and ridesourcing options, OTP SUM planned trips for both transit-only and transit+ridesourcing. The average trip cost for MOD OTP transit was $2.50, while the average overall trip cost was $8.50 to $11.50 for Transit plus the TNC and the average trip cost for TNC alone was between $11 to $33 (McHugh et al. 2021). In terms of transportation equity and accessibility, two out of six projects were focused on increasing mobility and accessibility to people with disabilities and underserved populations as follows:

- Pierce Transit planned an in-house paratransit service to support Wheelchair accessible service (WAV) requests. However, the pilot project received no requests for wheelchair-accessible vehicle trips (Grellier 2020).
- A key goal of the Valley Metro Mobility Platform was improving transportation accessibility using the Pass2Go app for persons with disabilities. Although the pilot number of riders with disabilities who used the app accessibility features was small, totally respondents with disabilities were satisfied with the app. Moreover, most respondents with disabilities reported improvements in their trip planning capabilities (Martin et al. 2020c).

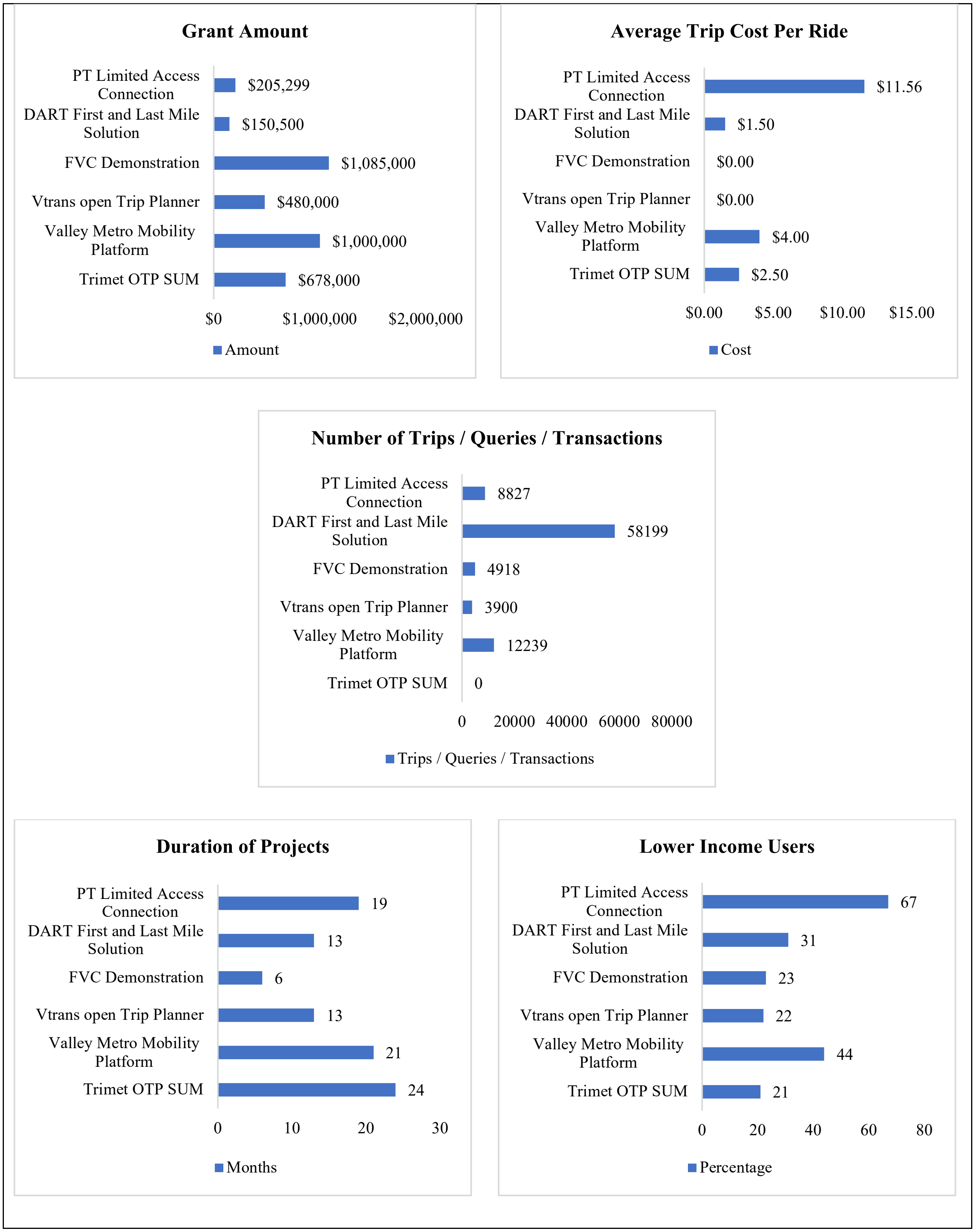

Figure 2-2 Comparing the key performance factors within the six selected programs

2.4 Discussion: Factors Identified for Establishing Well-integrated MOD into Current Planning and Modelling Practices

Exploring the main challenges, advantages, and lessons learned from the MOD Sandbox pilot projects indicate that the key success factor in these projects is the integration of app-based, on-demand services or TNCs into the existing public transit services. The MOD program providers face several challenges regarding integrating MOD into current planning and modelling practices, particularly in areas with multiple public-private providers or providers who serve limited geographical areas, with incomplete coverage across the city or region. There has been little research into identifying the key factors that contribute to the successful integration of MOD solutions into public transit, due to its novelty as technology.

Regarding the challenges and opportunities identified through the case studies in this study, we categorize the integration of MOD into public transit services based on five chief factors, including fare payment integration, physical infrastructure, scheduling integration, data sharing, and app integration (Weinreich et al., 2020b).

2.4.1 Fare Payment Integration

Regarding fare payment integration, app-based, on-demand pilot programs' payment policies are often based on passes and other programs previously existing in their regions of the United States. Integrating fare payment into a single user interface can reduce travelers' barriers while using multiple transportation modes and improve mobility accessibility and travel convenience. It also promotes travelers' decision-making by providing real-time information about the trip, reducing travel costs and travel time, and encouraging people to use public transit (Shaheen et al., 2020). A good example in this is DART, which used an existing fare pass policy for their pilot programs (Denton College Apartment Source, 2019; Golden et al., 2014; Weinreich et al., 2020b). Valley Metro is another example of successful fare integration with development of its "Pass2Go" app to integrate payment for multiple public transportation options (e.g., Valley Metro Rail and Valley Metro Bus service) (Martin et al., 2020a).

2.4.2 Physical Infrastructure

Physical infrastructure is critical in planning point-to-point, MOD services, particularly facilities at hubs intended to integrate services with fixed route services, sometimes connecting more than one transit agency. For example, DART provided dedicated parking bays and informational signage for app-based on-demand vehicles at one of its transit stations (Buckner Station) (Weinreich et al., 2020b).

2.4.3 Scheduling Integration

Schedule integration between services provided by different transit agencies is needed to improve rider experience through 1) timed transfers to reduce maximum wait times for passengers to transfer from one service to another, 2) app-based on-demand service during the hours not covered by the fixed route services, and 3) scheduled rides for on-demand services connecting to fixed routes. Valley Metro (AZ) is a good example for scheduling integration and developing a mobile application to allow users to access an optimized trip planning service. Valley Metro's Pass2Go provides travelers with real time travel information and allows them to choose specific travel itineraries based on different variables (Martin et al., 2020b).

2.4.4 Data Sharing

Data obtained from TNCs can provide insights into interactions with other transit agencies and modes in the broader regional transit system and assist with long-term service planning. Data sharing is necessary for real-time service adjustments based on fluctuating demands. One of the biggest challenges to implementing mobility on-demand services is getting the TNCs and transit agencies to agree on data sharing. Many transit agencies working with private TNCs have had trouble obtaining access to rider data, even for services integrating with their own platforms. For example, DART's GoPass feeds into Lyft's platform, but DART loses access to rider data as soon as the customer is transferred to the Uber platform in the booking process (Moran et al., 2017; Prashanth et al., 2019; Weinreich et al., 2020b). Additionally, Valley Metro planned to integrate private ridesharing services (Uber and Lyft) in its Pass2Go application, but the attorneys for Lyft expressed data privacy concerns due to the "Sunshine Law" in Arizona. Hence, Valley Metro could not integrate private TNCs within its application (Martin et al., 2020b).

2.4.5 App Integration

The multiplicity of private app-based, on-demand service providers has made it difficult to integrate multiple applications, as most private providers want the riders to use their own app. In contrast, the public providers are restricted to testing their pilot services. For example, Valley Metro could not integrate Lyft's application with its "Pass2Go" platform as they had concerns regarding user experience outside their platform (Martin et al., 2020b). DART developed its GoPass app to implement soft integration of the applications of private app-based, on-demand service providers (e.g., Uber and Lyft) (Parks et al., 2020). Efforts have been made to offer mobility as a service (MaaS), a digital service allowing users to access both private and public transportation services in a single application in Europe. For instance, UbiGo in Gothenburg, Sweden, is a pilot service that attempted to integrate ridesharing (car, bike), taxi, car rentals, and public transit services into a single platform providing a customized service package to its users through a subscription-based model (Sochor, 2016).

2.5 Conclusion

This study identified the challenges, potential opportunities and technical lessons learned while implementing the FTA Sandbox pilot projects in the US. We evaluated five factors, including 1) fare payment integration, 2) physical infrastructure, 3) schedule integration, 4) data sharing, and 5) app-integration, that assist with establishing a well-integrated public transit system using app-based on-demand technology.

Reviewing the MOD background revealed that most app-based on-demand pilot programs adopted their region's existing fare structure for fare payment integration. However, little research has been conducted on the integration of app-based on-demand services by transit agencies, and most app-based on-demand pilot services were designed without considering the need for future integration of applications. MOD public-private partnership has the potential opportunity for improving equity and mobility access by providing multiple mobility options through fare integration. Public transit agencies can utilize on-demand ridesharing service apps to promote their ridership. However, this potential can be challenging if the private service providers are unwilling to support fare integration with public transit agencies. Hence, fare integration should be considered the common goal of public and private service providers to increase travelers' convenience and decrease the transportation barriers of transit users.

Physical infrastructure, including land use, built environment, and transportation facilities, significantly influences pilot projects' success. The transit agencies and service providers usually require more physical infrastructure while operating through MOD services. However, it is notable that the financial costs related to the physical infrastructure of MOD services can be alleviated over time by increasing the demand for using these services. Another challenge the transit agencies face during implementation of their app-based on-demand pilot projects is obtaining trip-level data from their TNC partners. Therefore, it is crucial to execute proper policies and strategies to maintain the security of identifiable data in pilot projects before implementing the projects. Collaborating with universities to manage data, defining data sharing agreements to protect individual data privacy, and considering cybersecurity strategies while releasing data to the public are among the potential practices that could address data sharing issues (Shaheen et al., 2020).

Furthermore, using digital applications to integrate trip planning and fare payment and connect passengers to drivers is significantly associated with the success of the pilot projects (e.g., websites, apps). Digital applications facilitate the process of trip booking and fare payment for passengers. After evaluating the UbiGo service, Karlsson et al., (2016) suggested that successful integration of transportation services in a single platform needs cooperation (in terms of infrastructure, data sharing, and payment) and collaboration (among public and private transportation entities). However, MOD planners should develop alternative mechanisms and options for booking trips and fare payment for those travelers with no access to credit/debit cards. To help achieve transportation equity goals, MOD services could provide a call center, in addition to their digital platform, that enables passengers with less/no access to the internet to schedule their trips in advance using a phone. The technical lessons learned by the agencies during the pilot projects identified in the study will help policymakers better understand the challenges they may face in evaluating their existing policies and executing MOD projects.

Some other recommendations can be also extracted from the Sandbox evaluation. The general public needs time to adopt a new transportation service. Accordingly, marketing plays an essential role in the success of a project. Marketing can help transit agencies understand the mobility needs of actual and potential travelers and identify customer concerns and preferences towards using the service (Grellier 2020; Martin et al. 2021b). Performance evaluation during the service demonstration is essential; hence, it is recommended to develop accurate measures and metrics and identify how the service can be improved by modifications such as changes in service area, fleet and vehicle size and frequency and schedule of the service (Martin et al. 2021b). Pilot project evaluations reveal several opportunities for governments to collaborate with other stakeholders to increase the public interest, such as reducing traffic congestion, decreasing vehicle use, and improving air quality (Rupert 2020). Pilot projects' short-term results can evaluate their success, but these pilots can also have a longer-term impact if FTA employs the pilot findings in similar transportation projects in other regions (Martin et al. 2021a).

Future quantitative research is needed to measure the factors we identified in this study as the determinants of well-established MOD programs using real datasets from the pilot projects. There are several opportunities for future research in the MOD era, such as investigating the effects of MOD programs on travel behavior changes, particularly in terms of active travel modes. Moreover, additional research is required to identify how and to what extent MOD services have mitigated the transportation burdens and barriers of vulnerable communities, people with disabilities, senior adults, and low-income people.

CHAPTER 3

EXPLORING PREFERENCES TOWARDS INTEGRATING THE AUTONOMOUS VEHICLES WITH THE CURRENT MICROTRANSIT SERVICES: A DISABILITY FOCUS GROUP STUDY

3.1 Abstract

This study explores how people with disabilities perceive and accept autonomous vehicles (AVs) as a technology to improve their mobility. A focus group discussion was conducted to explore individuals' preferences towards integrating a level 4 AVs into the existing microtransit service in Arlington, Texas. Participants demonstrated a positive perception towards the integration of AVs into the current microtransit infrastructure. The results suggest that accessibility to a well-designed built environment is vital in adopting AVs by people with disabilities. Moreover, AVs' accessibility to healthcare facilities is one of the main concerns identified by focus groups of persons with disabilities. In particular, participants with visual impairment were hopeful that future AV services could improve their mobility through advanced apps, booking systems, and vehicle equipment. This study offers several implications for designing AV service in line with the needs of persons with disabilities while combining with the current microtransit service.

3.2 Introduction

According to the Social Security Supplement Survey of Income and Program Participation, 85.3 million people in the United States recorded a disability in 2014 (Taylor, 2018). The National Household Travel Survey (2017) indicates that 25.5 million people; 5 to 64 years of age in the United States; have a disability that impairs their ability to travel(Sprung & Chambers, 2016). Moreover, people older than 65 years of age will be 20 percent of the total population of the United

States by 2030 and their demand for riding public transportation services by them will increase rapidly in the coming years (Kaufman et al., 2016).

The emerging autonomous vehicle (AV) technology is expected to disrupt the existing modes of transportation and improve the mobility options (Hwang et al., 2020). Autonomous vehicles that is classified six levels of autonomy ranging from Level 0 "No Automation" to Level 5 "Full Automation"(Shuttleworth, 2019), has the potential of upgrading conventional personal vehicles and revolutionize transportation. The benefits of this new technology can be optimized while the relationship between the AV system and existing public transit be considered(Shen, Zhang, and Zhao 2018). Integration of the shared autonomous vehicles (SAVs) into the existing on-demand rideshare services could effectively reduce total travel time while the app-based services have the potential to schedule the pick-ups and drop-offs SAVs and collect or distribute the rides (Levin et al. 2019).

A significant number of US cities such as Arlington, TX, Boston, MA, Portland, OR, Pittsburgh, PA, San Jose, CA and Chandler, AZ have already initiated Level 4 AV pilot projects (Perkins et al., 2018). Studies suggest that using level 4 AVs could significantly reduce fatal accidents, traffic congestion, and fuel consumption (Woldeamanuel & Nguyen, 2018).

People with disabilities, particularly those who are visually impaired could benefit the most from AVs due to more comprehensive and convenient transportation options (Bennett et al., 2019). The literature has investigated the general public's attitudes, perceptions, and preferences for autonomous vehicle technology (Kassens-Noor et al., 2020);(Hulse et al., 2018); (Bezyak et al., 2017). Nonetheless, very little has been written about the perceptions of people with disabilities towards AVs as a public transportation mode.

To address these gaps, this study explores features contribute to the adoption of AVs by people with disabilities while considering their preferences towards integrating a wheelchair accessible AV fleet into the current microtransit service in the city of Arlington, TX. To achieve the objectives of this research we focus on a planned AV service pilot project known as RAPID (Rideshare, Automation, and Payment Integration Demonstration) in the City of Arlington, Texas. The City of Arlington will incorporate autonomous vehicles into its current app-based Via microtransit service under this initiative. Microtransit; introduced in 2012 in the US; is similar to city-operated paratransit or flexible route services using mobile apps and wireless connectivity to enhance the riders' accessibility to its' vans or small buses (Eby et al., 2018). Little is known about the factors influence the AV ridership due to the novelty of its operating system and the technology; less is known about the potential for adoption of emerging AVs by people with disabilities integrated in the service into microtransit transportation. Finding of this study provides insights into establishing and developing the AV service in line with the mobility needs expressed by people with disabilities. The interaction between the perspective AV players such as riders and the operating system plays a crucial role in the success of integration (Shen, Zhang, and Zhao 2018). Accordingly, identifying the transportation needs of the potential AV users can provide opportunities in recognizing how the performance of the overall system after the integration of AV into current transportation services can be improved.

3.3 Literature Review

Excessive dependence on personal vehicles for transportation in many US cities has caused mobility challenges for people with disabilities, making them dependent on others unless their city has an accessible public transportation system (Hwang et al., 2020). Previous studies indicate that lack of transportation is a significant barrier for people with disabilities when searching for employment (Sabella & Bezyak, 2019). People with disability are less likely to access healthcare facilities due to inadequate access to transportation and well-designed built environment (Jones et al., 2018; Pharr et al., 2019). Although access to public transportation has improved dramatically for people with disabilities since the enaction of the American with Disabilities Act of 1990, some accessibility barriers persist for people with disabilities while using public transit modes (Bezyak et al., 2017).

Autonomous vehicle technology has the potential of revolutionizing the transportation industry (Anderson et al., 2016). Autonomous vehicles (AVs) could serve those who are unprivileged (e.g., elderly and disabled), making it convenient for them to travel from one point to another with lower travel costs and better navigation (Freemark et al., 2019). The emergence of AV technology will lead to developing a new business model of shared autonomous vehicles, which could provide first and last-mile solutions through low-cost mobility services (Krueger et al., 2016). Due to the higher cost of sensors and complicated technology, most vehicles on the roads include only up to Level 3 autonomy (Van Brummelen et al., 2018).

To understand the rate of adoption and integration of the AV technology into existing modes of transportation, it is vital to understand the potential users' perception towards AV's (Penmetsa et al., 2019). Multiple studies have investigated the general public's perception of autonomous vehicles by focusing on the demographic and psychological factors (C. R. Hudson et al., 2019; Kyriakidis et al., 2015; Portouli et al., 2017; S. Wang et al., 2020) . According to Kyriakidis et al. (2015), most people from developed countries had significant concerns regarding software hacking and data misuse. People with high incomes are less likely to share an AV ride, while young people are more likely to share AV ride (S. Wang et al., 2020). Some scholars have studied the general public perception after riding a Level 3 autonomous shuttle and suggested that individuals perceive AVs as a travel option that could complement and not substitute for existing means of transportation (Hilgarter & Granig, 2020). Their results also revealed that older adults were more optimistic about AV's as compared to younger people, while males were more positive towards AV's as compared to females. Although many studies discuss the general public perception and acceptance of AV's, less attention has been given to their impacts on the mobility of people with disabilities (Bansal et al., 2016; Bennett et al., 2019, 2020; Hwang et al., 2020).

Reviewing the literature indicates that very little is known about the preferences and acceptance of autonomous vehicles for people with disabilities. This study aims to 1) explore the perceptions of people with disabilities towards the adoption of AV's, and 2) identify the factors affecting the successful integration of AV service into the existing microtransit services from the perspective of people with disabilities. Finally, this study provides insights to guide policymakers developing AV policies and regulations for people with disabilities.

3.4 Methodology

3.4.1 Case Study

Arlington, TX is the first city to employ AV technology as public transit for a pilot test, and therefore makes a meaningful case study for academics and practitioners to learn from. Arlington has also been implementing a traditional app-based, on-demand microtransit service (Via) since 2017, meaning that people in the city are familiar with the concept of on-demand transit, and can respond to many of the questions about AV services. This study investigates the potential users' perceptions of a proposed AV fleet in the Arlington, Texas. According to the United States Census Bureau (2019), the City of Arlington, with a land area of approximately 96 sq. miles, had a population of 398,854 in 2019, and people with a disability (less than 65 years old) represented 7.1% of its population in 2018. The mean travel time to work per day for workers with 16 years of age and older in the city of Arlington was estimated at about 27.4 minutes from 2015 to 2019 (U.S. Census Bureau, 2019). The median household income of Arlington was recorded $52,094 in 2010 (City of Arlington, 2019b). Although the city has not been served by fixed-route transit network, a microtransit service called Via provides ridesharing trips for the general public, including wheelchair accessible vehicles as necessary, in a portion of the city's area, including Downtown Arlington, University Campus, the Entertainment District, the Shopping Malls, and a commuter railway station. From its start in December 2017 through November 2020, the Via rideshare service has provided over 450,000 rides in Arlington, with a high of 1,055 rides on a weekday and 615 rides on a weekend. The Via service area has expanded incrementally and covered approximately 40% of the City's area in November 2020 (Ann Foss, personal communication, November 16, 2020).

To identify how people with disabilities adapt to future transportation options, we focus on a planned AV service pilot project known as RAPID (Rideshare, Automation, and Payment Integration Demonstration) in the City of Arlington, Texas. The Arlington RAPID project has been funded from the Federal Transit Administration under the Integrated Mobility Innovation program and conducted through a partnership between the City of Arlington, Via Transportation, Inc., May Mobility, and the University of Texas at Arlington. Under this project, the City of Arlington will integrate autonomous vehicles into its existing app-based Via microtransit service. This project serves as a demonstration project for the use of autonomous vehicles in public transit, integrating separate booking services, and implementing accessibility in AV service technologies.

3.4.2 Sampling and Data Collection

Rider acceptance is a potential limitation to use of a new service, especially a new technology, and understanding potential challenges for riders with specialized needs like those with accessibility limitations is key. Understanding this requires in-depth conversation with riders, and therefore, focus groups were used, rather than surveys, which would not produce a complete understanding of rider decision processes. Focus groups were chosen over interview formats as well, because of their usefulness for situations where all participants have experienced a similar situation (in this case, trying to get around Arlington, TX with a disability). Comments by one participant can trigger others to remember a similar situation they have undergone, providing the research team with a more complete picture. A seven-step approach was adopted for this study, as shown in Figure 3-1. People with disabilities who resided or worked in the City of Arlington were shortlisted for the focus group discussion, both from a general email to Via riders, and from members of the disability community recommended by city staff, who had worked on advocacy projects in the past. A screening survey was distributed among the shortlisted people to invite the focus group participants, who were chosen based on either their accessibility challenges, and/or their experience using microtransit. The research team scheduled the dates and times for the session and sent a doodle link to the selected participants to confirm their focus group discussion availability. While the authors recognize that an in-person focus group might have advantages in terms of helping participants feel comfortable talking about their experiences, the Covid-19 pandemic did not make face-to-face interactions possible. Due to the on-going Covid-19 pandemic and lockdown restrictions, the research team decided to virtually conduct the focus group discussion on the Microsoft Teams platform with the participants who accepted the focus group's invitation. However, it is noteworthy that only those people with access to the internet could participate in the focus group discussion as it was conducted virtually. The virtual format had certain advantages as well-making it easier for participants with mobility challenges to attend. A follow-up survey questionnaire was sent to the focus group participants. Focus group attendees were informed and consented to the recording of the session , in order to prepare a detailed transcript. Finally, the collected data were analysed by performing descriptive and conventional content analysis.

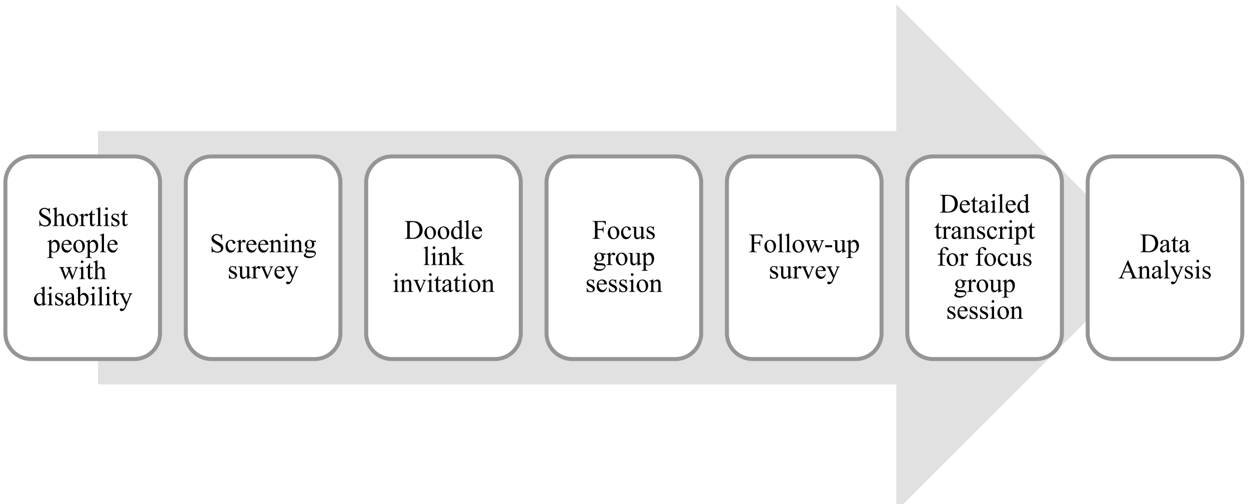

Figure 3-1 Research methodology

While the sample size was limited, so was the number of persons with disabilities in the City of Arlington. This limitation was mitigated by the fact that this was designed to be a qualitative study, based on in-depth responses of potential riders regarding existing microtransit services in the city, and AV services being proposed at the time of the focus group. The research team conducted the focus group session in August 2020, with the people with disabilities. A total of four participants with disabilities accepted the team's invitation. The focus group session was conducted by two moderators using a semi-structured guide of questions. The questions were designed to allow the participants to discuss their experience and ideas about the current and future transportation reasonably. Apart from the research team, an official member from the City of Arlington also attended the focus group discussion to answer any questions about the city's proposed AV service. At the beginning of the focus group, verbal consent was obtained from all the participants. After the focus group discussion, the research team sent a follow-up survey questionnaire to all the focus group participants to obtain information about their sociodemographic characteristics. The Institutional Review Board (IRB) approved the survey at the University of Texas at Arlington, prior to the implementation of the focus group session.

3.4.3 Data Analysis

This study utilized the qualitative content analysis method to analyse the collected data from participants. Qualitative content analysis is defined as the systematic classification process of coding and identifying themes or patterns as a research tool to subjectively interpret the content of text data (Hsieh & Shannon, 2005). Qualitative content analysis is one of the most used methods used by the urban and transportation scholars, which focuses on the contextual meaning of the text obtained from focus groups, open-ended survey questions, interviews, articles, etc. (Hsieh & Shannon, 2005). The content analysis method provides researchers to explore the trends and patterns that are hidden inside a large unorganized text data and allows them to evaluate the quantities of concerns underlying the textual contents (Das et al. 2017). The methodology of content analysis requires detailed steps, including designing the research questions and hypothesis, identifying the sample, defining the unit of analysis, choosing the enumeration systems, constructing the categories and sub-categories, and checking the validity of categories (Cullinane and Toy 2000). Using conventional content analysis method, the research team reviewed the focus group discussion transcript. After reviewing the transcript, the discussion themes were extracted in terms of preferences towards combining the proposed AV service into the existing microtransit service. Furthermore, different categories and sub-categories of each theme were extracted based on the information provided by the participants during the focus group discussion and the handwritten notes of the discussion.

3.5 Results

Results from follow up survey indicated that participants were white American females, with full-time or part-time employment, three of them had visual impairment and one had a physical disability. The focus group participants provided valuable information to the research team about their travel patterns and behaviors, mobility issues, and attitudes towards using Arlington's transportation services. The research team asked a question in the follow-up survey regarding the level of control of the autonomous vehicle with which participants were most comfortable with. Two participants were pleased with a shared control between the driver and the self-driving car, while the other participants choose not to answer it. The following sections describe the detailed results regarding the participants' main concerns and issues about the proposed RAPID autonomous vehicle service in Arlington.

3.5.1 Preferences of Autonomous Vehicle (AV) Service

The participants stated their preferences towards different attributes of the proposed AV service. Table 3-1 shows the disability focus group's preferences of the proposed AV service in Arlington.

3.5.1.1 Accessibility

People with disabilities preferred that the proposed AV services be spatially accessible by different residents living in various neighborhoods. When shown the map of service area, people with disabilities stated that it seems the AV service is inaccessible to the healthcare facilities and hospitals in North Arlington. One participant also expressed that it seemed the proposed AV service had focused too much on the campus area, and not on the areas of the city outside it, where they felt more of the disability community lived.

3.5.1.2 Safety

The participants showed a great preference towards an onboard safety assistant to help them during an emergency. Boarding an autonomous vehicle would be more convenient for people with disabilities if they perceive there would be someone to aid them. For the convenience and safety of disabled people, one out of the five AVs would be wheelchair accessible and equipped with a safety attendant in the proposed AV service. However, participants were in agreement that only one wheelchair accessible vehicle cannot support the mobility needs of persons with disabilities. While the facilitator stated that the future AV service will be provide by a safety attendant on all vehicles, one participant said that since it will be very helpful for boarding people with disabilities. Another participant noted that since the population of senior adults and people with disabilities is increasing, there is an urgent need for emerging transportation services to be more disability friendly.

3.5.1.3 Technology improvements

Since people with disabilities all have unique mobility needs, according to their disability, the facilitator asked them to describe preferences towards AV app booking system's features. A participant with visual impairments stated that designing the booking application with the screen reader's accessibility could help people with visual impairments. However, she believed that they should test the facilities designed to mitigate the mobility needs of disabled people. Another participant suggested integrating Apple Pay, Google Pay, or Samsung Pay into the payment system for future AVs as these methods are more convenient for people with disabilities. One participant expected the AV application could provide riders with the exact pick-up location, which has not been a feature of the Via service to date. Therefore, if the driver cannot locate them, they can share their location with the driver.

Table 3-1 Disability focus group findings regarding mobility preferences of future AV services

Theme	Subtheme	Details
Geographical Accessibility	Health Care Accessibility	- "If AV coverage went a little bit further North, that would be just to even get the hospital over there that would be great actually, I guess."
	UTA Centered	- "You're not just serving AV to students, you're also serving the community as a whole, I think the AV coverage should be a little more spread out maybe."
Safety	Presence of Human Operator	- "There would probably still be some sort of live person onboard the autonomous vehicle just to assist in case of an emergency." - "Five of the vehicles should have the safety attendant and should be trained for boarding."
Technology improvements	App Booking System	- "Make a screen reader accessible for blind people and let a blind person test it." - "Integrate Apple Pay or Google Pay or Samsung Pay to the payment system, it's so much easier for those who are disabled in that mobility and dexterity problems." - "Since I can't physically look for the vehicle, if I can say I am at a place of business and the AV supposed to meet me in a parking lot. I would hope that I would be able to say somehow, OK, I'll be standing outside XYZ business to driver."
	Vehicle Equipment	- "What kind of flooring you guys have in the autonomous vehicles, because so many of us have service dogs and having mats in the floor keeps the dogs from sliding."
	User Profile	- " People can enter their disability needs in their user ID AV application, and AV adjust the pick-up point based on the disable person's needs." - "Since you cannot communicate with the AV's. So, it would be nice if disable people can put their needs such as the pick-up point to their user ID."
Improving the built environment	Lack of sidewalk, ramp and curb cuts	- "We definitely need to pick up in places with good sidewalks, but we also need places with good ramps and shelters as well." - "I would say hire a consultant, who either has a whole lot of disability experience or hire somebody with a disability and be sure that they work with a team of people with disabilities to determine what will work for the most people."

Participants also suggested some technological preferences about the vehicle and cabin. They stated that since some people have service dogs while boarding the vehicle, having a mat on the floor keeps dogs from sliding. Furthermore, a participant suggested that the AV service application's user profiles should include information regarding their disabilities, allowing them to select their route and stops based on their mobility needs.

3.5.1.4 Improving the built environment

Participants of the disability group affirmed that one of the most significant desires they have is an improved built environment based on their mobility needs (e.g., equipping the pick-up and drop-off points with shelters and ramps). They suggested that AV operators could take help from professionals with experience in the mobility needs of disabled people to determine what will work for them.

3.6 Discussion and Conclusion

Focus group participants generally showed a positive perception towards the AV service. This finding confirm the previous studies that suggest AV service can be accepted by people with disabilities in order to improve their transportation accessibility (Hilgarter & Granig, 2020; Hwang et al., 2020; S. Wang et al., 2020). However, results indicate that disabled people are not interested in riding entirely self-driving vehicles. This result follows the research suggesting that disability groups require trained operators to assist those who need help in boarding the vehicle (Hwang et al., 2020). Policymakers should consider this factor while developing and integrating transit systems using AV technology. And while specializations like rider attendants and predictable stop locations may cost additional money, these are some of the costs necessary to make the service work for riders with disabilities—and may still be affordable when compared to the cost of running paratransit services.

In addition to service costs, it is critical for transit agencies to inform the public about their service offerings through information campaigns considering the fact that many people with disabilities will be skeptical about a service with which they are still unfamiliar (Bennett et al., 2019). In order to promote the use of AVs, local or state governments can provide incentives to the people who opt to use AVs as a mode of transportation, particularly if they opt to use it instead of more costly like paratransit.

Results suggest that access to health care providers is among the most crucial needs for people with disabilities. Similar to previous studies, our participants said that lack of mobility can prevent seniors and people with disabilities from accessing health care facilities in distant areas. Public transit dependent population are more likely to miss appointments or have late arrivals compared to those who use private vehicle as to travel to health care facilities (Rask et al., 1994; Wallace et al., 2005). Accordingly, adding to the existing routes, increasing operating hours, and providing more frequent services are among the policies that public transit service could apply to improve patients' accessibility to treatment and care (Litman, 2013).

Additionally, we note that access to an appropriate built environment was a vital factor either contributing to or impeding people with disabilities' likeliness of using the service. This finding suggests that inaccessible built environments are obstacles to people with disabilities use of current microtransit service. The local and state government should focus on redeveloping the existing infrastructure suitable for the emerging technology before integrating AV's into the current transportation services.

Lastly, we would like to note few limitations to this study-which need to be addressed when doing future research. The major limitation of this study is related to the few number of individuals who participated in the focus group discussion. Since this study was conducted concurrent with the spread of Covid-19, the sample size was limited and small. Accordingly, exploring the preferences of a greater number of participants with different disabilities could increase the validity of the further research in this era. This study focuses on the combination of emerging transportation with current microtransit services; future studies should be conducted to recognize the integrations of AV service into other transportation options including paratransit services. A more diverse range of studies of this type will be made possible as the range of microtransit service models grows, and the number of AV-microtransit systems expands over time.

Acknowledgment

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CHAPTER 4

HOW RIDERS USE SHARED AUTONOMOUS VEHICLES

4.1 Abstract

Autonomous Vehicles are expected to play a crucial role towards achieving sustainable transportation in the near future. Consequently, it is vital to acquire insights into the public's acceptance of shared autonomous vehicles (SAV) for the successful integration of SAVs into the existing transportation infrastructure. This study aims to identify the factors affecting users' frequency of riding SAVs using data obtained from riders of an SAV service in Arlington, Texas. A structured survey is developed to gather data related to SAV riders general travel behavior, attitude towards the SAV service attributes, frequency of using the SAVs, and sociodemographic characteristics. We develop our conceptual framework based on the relationship between key variables and frequency of SAV usage. Employing Structural Equation Modelling, this study explores the interrelations between users' sociodemographic characteristics, SAV attitude, and general travel behavior and their effects on the frequency of using SAVs. Results indicate that race, trip purpose, waiting time and private vehicle significantly impact users' frequency of using SAVs. Our model also identifies the impacts of user attitude towards service attributes on the frequency of using SAVs. This study provides insight to transportation planners and policymakers about SAV service and its usage in a low-density area, enabling them to develop policies and transportation infrastructure accordingly to enhance SAV operations universally.

4.2 Introduction

Autonomous Vehicles (AVs) are anticipated to revolutionize transportation by improving the quality of life and road safety (Wiseman, 2022). AVs are expected to provide multiple advantages in terms of reducing the need for parking space in city centers, improving mobility for unlicensed and disabled people, reducing car accidents, traffic congestion, and fuel consumption (Fagnant & Kockelman, 2015; Haboucha et al., 2017). However, studies have also emphasized on potential challenges of the emerging AV technology that might be countered during the transition from traditional to automated transportation systems (Hilgarter & Granig, 2020; Hulse et al., 2018). The emerging AV technology is also expected to change individual travel behavior by allowing people to move to suburban areas thereby changing the structure of urban configuration (Jing et al., 2020).

The short- and long-term adoption of AVs can be predicted by identifying the user attributes and their travel behavior (Bansal et al., 2016). Since fully autonomous vehicles have not yet been deployed and tested on public roads, there is a persisting challenge of understanding AV users' characteristics, travel patterns, and travel behavior (Kim et al., 2020). In recent years studies have been conducted to explore individuals' perceptions towards AVs and SAVs . A study by (Moody et al., 2020) focused on identifying individual differences in perception of AV safety from 51 countries around the world. It was found that individuals from developing countries with great road safety challenges were more optimistic while individuals of developed countries with higher motorization rates and road fatalities were pessimistic about AV safety at present or in the coming years. (Lavieri et al., 2017) suggested that lifestyle factors might significantly impact the use of autonomous vehicles, suggesting young, highly educated, tech-savvy, and urban residents are more likely to adopt the AV technology as compared to older and rural residents.

A few previous qualitative studies have focused on obtaining data from actual users of SAVs through personal interviews. In September 2018, (Hilgarter & Granig, 2020) conducted semi-structured interviews of 19 users of Level 3 automated shuttles in Austria on a predefined track with a speed of 10 km/hr. The results suggested that people from rural areas were more optimistic about AVs as compared to people from urban areas. A study by (Nordhoff et al., 2019) conducted interviews of 30 users of an automated shuttle used as a feeder to the public transport system in Berlin. They found that service quality was one of the most significant determinants of the acceptance of SAVs, and users were more comfortable having an operator onboard the vehicle as compared to full automation. In 2017, (Salonen & Haavisto, 2019) collected data from 44 individuals who traveled in an automated shuttle bus in Finland through semi-structured interviews. Using the Theory of Interpersonal Behavior (TIB), they found that people felt safe while using the automated shuttle bus but are less tolerant to accidents caused by AVs as compared to those caused by human drivers.

However, the majority of studies have relied on data obtained from potential users through consumer preference surveys (Abraham et al., 2016; Gkartzonikas & Gkritza, 2019; Haboucha et al., 2017; Jiang et al., 2019). These surveys focused on identifying the Connected Autonomous Vehicles (CAV), adoption, risk preference, SAV adoption, and willingness to pay (Asgari & Jin, 2019; Asmussen et al., 2020; Morita & Managi, 2020; Nickkar et al., 2020; Sharma & Mishra, 2020; Wang & Zhao, 2019).

The literature excludes empirical studies of user adoption of AVs based on actual ridership data. As a result, this study aims to fulfill this gap by identifying the factors affecting the frequency of using the SAVs by utilizing the data collected from the users of an SAV service. Secondly, most prior studies have focused on large metropolitan areas with multiple transportation options. This study focuses on user adoption of SAVs after integrating an SAV service into existing transportation infrastructure in a low-density area and a city with no public transportation. To fulfill the objectives of this study, a short survey was administered to the users of the RAPID (Rideshare, Automation and Payment Integration Demonstration SAV service in Arlington, Texas. A list of questions was developed asking users to rate their opinion about trip features, service attributes, and sociodemographic characteristics to help understand the role of these key variables for SAV adoption. The findings of this research will help policymakers and transportation planners understand the factors impacting the frequency of using an SAV service in a low-density area.

4.3 Methodology

4.3.1 Case Study

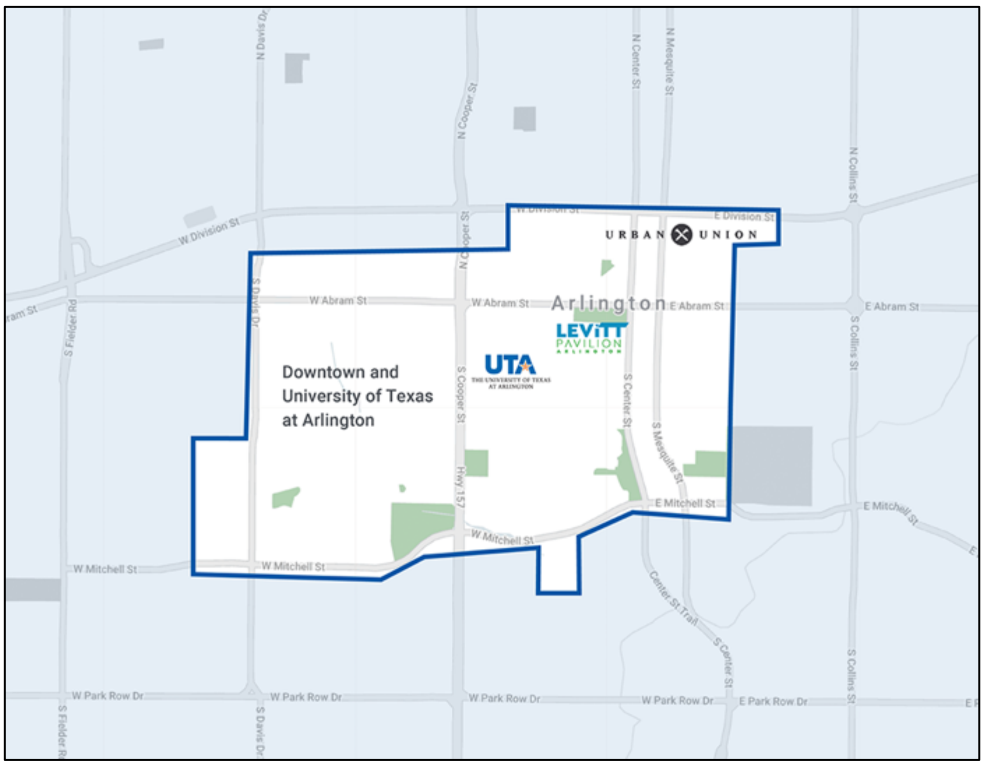

Figure 4-1 RAPID Service Area

The Arlington RAPID (Rideshare, Automation and Payment Integration Demonstration) is a pilot project funded by the Federal Transit Administration (FTA) through the Integrated Mobility Innovation (IMI) program. The pilot project is expected to run for a year from March 2021 to March 2022. The City of Arlington partnered up with major stakeholders like Via Transportation, May Mobility, and the University of Texas at Arlington to successfully manage this project. Under the Arlington RAPID project, the city operates an on-demand AV transportation service with the existing transportation infrastructure in downtown Arlington and the UTA campus area providing free rides to students. The service is fully on-demand with four Lexus hybrid vehicles and a Polaris GEM vehicle (wheelchair accessible) that operates on weekdays from 7:00 AM to 7:00 PM (City of Arlington, 2021b). The general public can use the service at the same price as the existing Via Ridesharing service that has operated in the city since December 2017 (City of Arlington, 2019a). Figure 4-1 shows the service area of the Arlington RAPID project.

4.3.2 Data Collection

The RAPID project research team developed a short survey to gather data from the users of the RAPID AV service based on the focus group discussions conducted before the implementation of the project (Etminani-Ghasrodashti et al., 2021a, 2021b; Patel et al., 2021). The target population of the study was anyone above the age of 18 who works, studies, or lives in Arlington and has used the RAPID service at-least once. The survey was reviewed and approved by the Institutional Review Board (IRB) at the University of Texas at Arlington. The survey consisted of 16 questions asking users about their trip purpose, service attributes, usual modes of transport, frequency of using the RAPID AV service, and sociodemographic characteristics. The survey was developed in the QuestionPro platform and distributed by Via Transportation (operator of RAPI AV Service) thorough their app to the users of the RAPID AV service. Among the 1,194 people who viewed the survey, 388 people responded by filling it out. Only 252 responses (65%) were completed responses. However, 136 people left the survey without completing it. The average time taken to complete the survey was approximately 2 minutes.

4.3.3 Compilation of Dataset

Table 4-2 Descriptive Statistics of Survey Participants

Sociodemographic	Description of Variable	Frequency	Percentage
Gender	Male	71	28.74
	Female	166	67.21
	Other	3	1.21
	Prefer not to answer	7	2.84
	Total	247	100
Age	18-24	135	53.78
	25-34	93	37.05
	35-64	22	5.58
	45-54	4	1.59
	55-64	4	1.59
	65 and above	1	0.41
	Total	251	100
Race	American Indian or Alaskan Native	4	1.61
	Asian	145	58.47
	Black or African American	47	18.95
	White	32	12.9
	Other	20	8.07
	Total	248	100
Vehicle Ownership	No vehicle	120	48.98
	One vehicle	80	32.65
	Two vehicles	25	10.2
	Three or more vehicles	20	8.16
	Total	245	100
Annual Household Income	Less than $35,000	180	75.95
	$35,000 to $74,999	36	15.19
	$75,000 and more	21	8.86
	Total	237	100
RAPID Usage	This is my first time	82	32.67
	This is my second time	33	13.15
	About once per month	11	4.38
	About twice per month	21	8.37
	About once per week	23	9.16
	About twice per week	81	32.27
	Total	251	100
Trip Purpose (More than one response)	Work	39	15.48
	School	89	35.32
	Shopping	18	7.14
	Medical	7	2.78
	Social and recreational	19	7.54
	Returning Home	59	23.41
	Others	21	8.33
	Total	252	100

4.3.3.1 Sociodemographic

We collected information related to sociodemographic factors (gender, age, race, ethnicity, educational background, employment status, household income, vehicle ownership) of the survey participants. Table 4-2 shows the descriptive statistics of the survey participants. The results show that most survey participants (67.21%, n=166) were female suggesting that females were more interested in using the RAPID service as compared to their male counterparts. A large majority of the participants (90.83%, n=228) were young individuals (18-34 years). More than half of the population were young Asian (58.47%, n=145) individuals, followed by African American (18.95%, n=47) and White (12.9%, n=32), respectively. About a half (48.98%, n=120) of them had no access to a private vehicle, while the other half (51.02 %, n=125) had at least one private vehicle in their household, suggesting an equal distribution of population with access and no access to private transportation. A majority (78.63%, n=195) of the survey respondents were UTA students. The sample distribution is in line with the targeted population of the RAPID Arlington project, which was students and people from lower-income households with limited mobility, working or living in the city of Arlington.

4.3.3.2 Waiting Time

To understand their travel behavior, RAPID users were asked about the duration they had to wait for the RAPID AVs to arrive at their location. Results indicated that 60% of the users had to wait for less than 10 minutes for the AV to arrive at the pick-up location, and the other 40% had to wait for more than 10 minutes.

4.3.3.3 Existing Modes of Transportation

Past studies have emphasized the impacts of individuals' travel modes and daily travel patterns on the adoption of SAVs (Krueger et al., 2016; Wang & Akar, 2019). Since Arlington does not have a fixed route transit system service, we asked the respondents about their *existing modes of transportation* like Via Ridesharing Services, Private On-Demand Transportation Services (Uber and Lyft), UTA Transportation Services, Walking/Biking, and others. Results indicated that among the 250 participants who responded, about one quarter (27.60%, n=69) of the respondents use the Via Ridesharing service, followed by private vehicles (25.2%, n=63), walking/biking (19.6%, n=49), private app based on-demand services (Uber & Lyft) (13.6%, n=34), UTA transportation (8.4%, n=21) and others (5.6%, n=14).

4.3.3.4 Trip Purpose

In order to understand the travel patterns of RAPID users, participants were asked about their purpose of using the RAPID service. Their responses were asked in seven categories (work, school, shopping, medical, social and recreational, returning home and others). Going to work, school, and returning home were the most frequent trip purposes among the survey participants.

4.3.3.5 Service Attributes (RAPID)

Existing literature suggests that the attitude of the general public towards adopting AVs and SAVs is crucial (Asgari and Jin 2019; Lavieri et al. 2017; P Liu et al. 2019a; Xing et al. 2020; Zhang 2019). Eight individual statements, in the survey, measured the user's attitude towards RAPID SAV services. These statements were related to 1) SAV features like speed, seating comfort, and climate control, and 2) AV service attributes, such as the ability of the AV to interact with other vehicles on the road, ridesharing with other passengers, and cleanliness of the vehicle. The respondents were asked to report their perceptions based on the 5 points Likert scale (where 1=very poor, 2=disagree, 3=neutral, 4=agree and 5=strongly agree). Furthermore, we performed factor analysis using the SPSS AMOS V.28 software to decrease variables and obtain a latent factor. All these statements were factor analyzed using Principal Component Analysis (PCA) and Varimax (orthogonal) rotation. A single factor "Service Attributes" was extracted explaining 56.38% variance of the entire set of variables with a Kaiser Mayer Olkin (KMO) = 0.877 (see Table 4-3).

Table 4-3 Component Matrix for Attitude Towards RAPID Service Attributes

Please share your opinion of your ride today. (From 1: Strongly Disagree to 5: Strongly Agree)	**Factor Loadings**
	Service Attributes
1. Booking and scheduling my RAPID trip using the Via app was easy	0.643
2. The waiting time was reasonable	0.620
3. The pickup and drop off locations were convenient	0.660
4. Boarding the vehicle was easy	0.758
5. The seats in the vehicle were comfortable	0.786
6. The climate control in the vehicle was appropriate	0.700
7. The speed of the vehicle was reasonable	0.744
8. I felt safe when riding RAPID	0.784
% Of Variance	**56.38%**

Previous studies developed models related to AVs and SAVs adoption by exploring sociodemographic variables and individual attitudes (Wang & Akar, 2019; Wang & Zhao, 2019). However, due to very few autonomous vehicles pilot services and minimal access to ridership data, most past studies focused on the data collected from potential users and non-users of AVs or used simulations or consumer and preference surveys to predict general public behavior towards autonomous vehicles, instead of studying actual users. We developed our conceptual framework considering the actual SAV users and factors affecting the utilization of emerging technology, as shown in Figure 4-2.

4.3.4 Conceptual Model

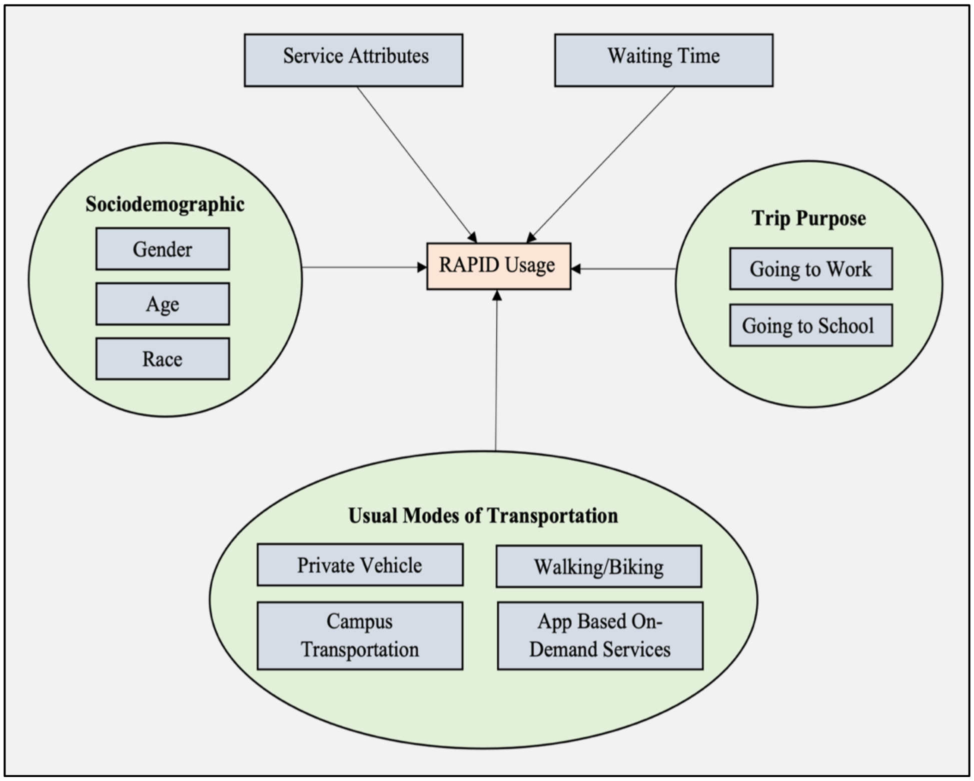

Figure 4-2 Conceptual model developed for the study

Past studies have suggested that attitude towards autonomous vehicles play a crucial role towards AV acceptance and adoption (J. Hudson et al., 2019; Jiang et al., 2020; Rahimi, Azimi, & Jin, 2020; S. Wang et al., 2020). A study by (Krueger et al., 2016) indicated that service attributes like trip time, waiting time, and price are some of the significant determinants for the acceptance of SAVs. We hypothesize that an individual's attitude towards RAPID service attributes and waiting time would play a significant role in predicting the frequency of using the service.

Daily travel habits can predict the extent to which people will accept and use SAVs in the future (Haboucha et al., 2017). Since Arlington is the largest city in the United States without a mass transportation system (Harrington, 2018), we developed our conceptual model considering that the existing modes of transportation would directly impact the users' willingness to use SAVs.

Vehicle ownership has been shown to be a factor that can affect individuals' travel behavior and acceptance of emerging mobility modes (Menon et al., 2019). Accordingly, we assume that vehicle ownership can affect an individual's choice of using the RAPID service. We predict that people with access to private vehicles will use the SAV service less frequently.

Past studies have identified the impact of sociodemographic factors on AV adoption (Zoellick et al., 2019). In our model, we assume that sociodemographic factors, including age, race and gender, can indirectly influence RAPID usage.

The conceptual model of the present study considers direct effects of key variables on frequency of using the RAPID service. Moreover, the model evaluates the interrelations between key variables. Accordingly, we performed structural equation modelling (SEM), a technique useful for modelling and testing complex multi-dimensional concurrent relationships between independent and dependent variables using the SPSS AMOS V28 software. Furthermore, we used the maximum likelihood estimation technique to obtain model parameters.

4.4 Results

In order to evaluate the fitness of the hypothesized model with the observed data three model fit indices, namely the ratio of the Chi-Square Statistic to Degrees of Freedom (χ^2/df), the Root Mean Square Error of the Approximation (RMSEA), and the Comparative Fit Index (CFI), were considered. Since the value of Chi Square Statistic is affected by large sample size, the literature suggests using the ratio of ($\chi^2/df < 5$) as a measure of goodness of fit. The value for (χ^2/df) for the hypothesized model was 1.247 indicating a good fit between the hypothesized model and the observed data. According to (Hu & Bentler, 1999) the cut off values of RMSEA (<0.06) and CFI (>0.95) differentiate good fitting models from poor fitting models. The RMSEA and CFI value for the hypothesized model are 0.032 and 0.951, respectively, indicating a good model fit as shown in Table 4-4.

Table 4-4 Model Fit Indices

Model Fit Indices	χ^2/df	CFI	RMSEA
Model Fit Criteria	<5	>0.95	<0.06
Actual Value	1.274	0.951	0.032

Table 4-5 PATH Coefficient Estimates for Direct Effects of the Key Variables

Direct Effects of Key Variables on Frequency of Using the RAPID Service	Standardized Estimate	Standard Error	Critical Ratio	P - Value
Age (Above 24)	0.032	0.256	0.540	0.589
Race (Non-White)	0.145	0.281	2.252	0.024*
Gender (Female)	0.027	0.290	0.445	0.656
Service Attributes	0.115	0.131	1.890	0.059*
Waiting Time	0.247	0.122	4.064	0.000*
Trip Purpose (School)	0.117	0.277	1.903	0.057*
Trip Purpose (Work)	0.204	0.367	3.266	0.001*
Private Vehicle	-0.253	0.348	-3.604	0.000*
Campus Transportation	-0.018	0.478	-0.287	0.774
App Based On Demand Services	0.013	0.400	0.206	0.837
Walking Biking	-0.029	0.359	-0.438	0.661

Note: * Significance at $\alpha = 0.05$

The results in Table 4-5 indicated that race had a significant positive relationship with the frequency of using SAVs, implying that the non-white population was more likely to use the RAPID service frequently. Moreover, service attributes had a significant positive relationship with the RAPID usage. In general, people who had a significantly positive attitude towards the RAPID service operations in terms of booking and scheduling the trip, comfort, safety, and convenience in terms of pick-up and drop-off locations or boarding the vehicle were more likely to use the RAPID service frequently. Surprisingly, waiting time had a significantly positive relationship with the frequency of using SAVs, indicating that people who had to wait too long for the RAPID vehicle to arrive at their location were more likely to use the RAPID service frequently.

Trip purposes (Work and School) had a significant positive relationship with RAPID usage, implying individuals using the RAPID service for the purpose of going to work and school were likely to use it more frequently as compared to individuals who use it for other purposes. On the other hand, private vehicles had a significant negative relationship with the frequency of using SAV service, suggesting people using private vehicles for their transportation were unlikely to use the RAPID service frequently.

4.5 Discussion & Conclusion

The main objective of this research was to identify the factors affecting users' frequency of riding Shared Autonomous Vehicles based on a short survey developed by the research team to get input from RAPID SAV service riders. Consequently, we conceptualized our study model based on actual ridership data considering sociodemographic variables (age, gender, race), service attributes, usual modes of transportation, trip purpose and RAPID usage. Since the RAPID project focuses its operations near downtown Arlington and UTA campus, the descriptive statistics of survey participants suggested that the majority of the RAPID service users were young Asian individuals from low income households with no or limited access to private transportation. As a result, most of these individuals were frequent users of the existing transportation services in the city like Via (89.29%) and UTA Transportation (51.59%). However, these results suggest the RAPID project achieved its primary aim of providing transportation equity to people from lower-income households with limited mobility working or living in the city of Arlington.

We employed Structural Equation modelling to identify the relationships among multiple key variables. The results indicated that the non-white population was more likely to use the

RAPID service frequently. These results were expected as the RAPID service focused its operations near the UTA campus, and the international students living on campus were more likely to use the RAPID service for their daily travel.

The results from SEM showed that SAV service attributes were a significant factor for the frequency of using SAVs. This implies that people with a positive attitude towards RAPID service attributes were more likely to use the service frequently. These findings supports the findings by (Krueger et al., 2016) indicating service attributes plays a significant role towards acceptance of SAVs. These findings suggest that promoting service attributes like the ease of booking and scheduling a trip via mobile app, the comfortable seating, the safety, and the convenience in terms of pick-up and drop-off locations or boarding the vehicle might increase the use of SAV services.

Results indicate a significant positive relationship between trip purpose and RAPID usage, implying that people who were using RAPID for going to school and work were more likely to use it frequently. These findings were expected as the RAPID service area was focused around Downtown Arlington and UTA campus, and most users were expected to be students living around campus and people living or working in the surrounding area.

Results indicate that people with access to a private vehicle were more likely to use the RAPID service frequently. These results are in line with (Shabanpour et al., 2018) indicating that millennials with higher incomes were more likely to adopt the AV technology. On the contrary, the descriptive statistics of RAPID users indicates that most RAPID users were from lower income households (less than $35,000). These results indicate that people from lower income household with limited mobility options are bound to use the existing modes of transportation.

This study provides insight to transportation planners and policymakers about SAV service and its usage in a low-density area, enabling them to develop policies and transportation infrastructure accordingly to enhance SAV operations universally. However, there are certain limitations to this study. Since the research was developed during an ongoing pilot demonstration, individuals' travel behavior might change after the newness of the emerging AV technology has ended. Moreover, the number of responses on the survey was low due to students avoiding campus due to the Covid-19 pandemic and the availability of online classes. There is a need to reconduct this research in the post-deployment phase of the project with a more comprehensive dataset. Future studies can be developed based on the findings of this research by developing a comprehensive set of questions related to factors affecting the frequency of using SAVs or their acceptance in different parts of the United States to generalize these findings.

Acknowledgement

This work is part of the Arlington RAPID (Rideshare, Automation and Payment Integration Demonstration) project supported by the Federal Transit Administration under its Integrated Mobility Innovation (IMI) program funded by the United States Department of Transportation (USDOT). The project comprises of the following partners: the City of Arlington, May Mobility, Via Transportation, and the University of Texas at Arlington.

CHAPTER 5

EXPLORING WILLINGNESS TO USE SHARED AUTONOMOUS VEHICLES

5.1 Abstract

Although multiple studies have modeled and predicted the potential effects of shared autonomous vehicles (SAVs), the research on the adoption of SAVs by riders with actual ridership experience is still limited. In addition, the increasing tendency towards operating SAV technology requires understanding its efficiency while integrating it into the existing transportation network infrastructure. This study aims to identify the factors affecting the user's willingness to ride the SAVs based on the data collected from a comprehensive survey distributed among users and non-users of a self-driving pilot project called RAPID (Rideshare, Automation, and Payment Integration Demonstration) in Arlington, Texas. Using structural equation modeling (SEM), we identify the effects from vehicle ownership, RAPID usage, existing modes of transportation, RAPID service attributes (comfort and safety), and sociodemographic variables on individuals' willingness to use SAVs in the future. Results indicate that most riders of the RAPID service are young Asian individuals and students from low-income households with limited or no access to a private vehicle. Furthermore, SEM results show that RAPID usage directly impacts willingness to use SAVs, implying that people start developing trust for the technology with an increase in the frequency of using the service. Our model suggests that sociodemographic attributes of the SAV riders indirectly influence the willingness to use SAVs through the mediators, including RAPID usage, existing modes of transportation, and vehicle ownership. This study provides crucial insights about individual travel behavior after integrating SAVs into existing transportation infrastructure to assist policymakers and transportation planners in developing AV-related policies.

Keywords: shared autonomous vehicles; willingness to use, travel behavior, travel mode

5.2 Introduction

Mobile internet advances have initiated ridesharing and ride-hailing services that discourage people from using privately owned vehicles and public transit services (Kim et al., 2020, Patel et al., 2022a). Similarly, shared autonomous vehicles (SAVs) are a new technology that allows passengers to skip hailing a cab by using a smartphone app to summon an autonomous shuttle that does not require a human operator (Fagnant & Kockelman, 2014). This technology will alter human travel patterns and bring significant changes to the existing transportation infrastructure (Zhang et al., 2015). Autonomous vehicles (AVs) can solve current transportation issues by improving road safety through fewer car crashes, reduced traffic congestion, positive environmental impacts, fuel efficiency, and amplify public health. (Fagnant & Kockelman, 2015; Haboucha et al., 2017). SAVs can also provide first and last-mile options by providing transportation services on routes that are in less demand and complementing existing public transportation services (Etminani-Ghasrodashti et al., 2022a). An added plus is that since users do not have to interact with the vehicle, they can devote extra time to work or leisure activities (Krueger et al., 2016).

The challenges of understanding AV users' characteristics, users' travel patterns, and behavioural changes arise because fully autonomous vehicles have not yet been demonstrated on streets and highways (Kim et al., 2020). Previous research studied the public's opinion of AVs to better understand their preferences and concerns regarding the technology (Chikaraishi et al., 2020; Das et al., 2020; C. R. Hudson et al., 2019; Woldeamanuel & Nguyen, 2018; Xu & Fan, 2019), but because of the limited number of people with real-life experience in self-driving cars, they usually relied on data collected through surveys of potential consumers (Abraham et al., 2016;

Asgari & Jin, 2019; Gurumurthy & Kockelman, 2020; Wu et al., 2020). As a result, existing literature lacks the modus operandi to extract the factors affecting individual's willingness to use the emerging SAV technology based on actual SAV ridership data.

The majority of past research were conducted in urban areas with numerous public transportation options, using data from potential SAV users. (Wang & Akar, 2019; Wang & Zhao, 2019). To best of our knowledge, and in the time of our study, no research has been performed regarding a self-driving vehicle operating on the road as a shared transportation mode. To address this gap, this study investigates SAV adoption by people already using an SAV service merged with existing ridesharing service in the city without traditional public transportation. To achieve the objectives of this study, we focused on the data collected through a comprehensive survey administered to the users and non-users of the pilot SAV service deployed in Arlington, Texas. The survey consisted of multiple sections with close-ended and a few open-ended questions focusing on SAV usage and perception, concerns and preferences towards SAV, usual travel patterns, residential accessibility, and sociodemographic variables. The outcomes of this research will assist regulators and government transit agencies in identifying the significant factors impacting users' willingness to use SAVs in the future. In addition, it will help the marketing companies by identifying the demographic and behavioural segmentation of SAV users.

5.3 Literature Review

Autonomous vehicles are a new form of transportation that allows riders to get from one point to another without any human intervention (Manfreda et al., 2021). Autonomous vehicles have been broadly classified into six levels by the Society of Automotive Engineers (SAE) ranging from Level 0 to Level 5 (no automation to full automation) (Society of Automotive Engineers, 2021). According to researchers, autonomous vehicles will account for over 90% of the entire fleet by

2055, with AV technology likely to be operational by 2030 (Greenblatt & Shaheen, 2015). As of 2021, 35 states have passed legislation or issued executive orders relating to autonomous vehicle technology in the United States (National Conference Of State Legislatures, 2021). According to researchers, the integration of autonomous vehicles with shared mobility technology would contribute significantly to attaining sustainable transportation. On-demand mobility services have emerged as a transportation mode that provides temporary access to vehicles for a short period (Shaheen & Bouzaghrane, 2019). Ridesharing (individuals with a common origin/destination or both share a vehicle), car-sharing (access to a shared vehicle for a limited time), ride-sourcing services (links drivers with passengers using smartphone application), and electronic hailing (E-Hail) (allows passengers to hail a taxi on-demand via a mobile application) are all examples of on-demand mobility (Greenblatt & Shaheen, 2015). In recent years 17 Level 4 SAV pilot projects have been deployed in 8 states throughout the United States (Stocker & Shaheen, 2019). These pilot projects were operating mainly under two scenarios 1) University Campus and Planned Communities and 2) Public Roads. Approximately 53% of these pilots were in the testing phase with pre-selected passengers, and 47% provided a ride to the general public. However, there haven't been many AVs or SAVs on road yet, and it's vital to identify the significant determinants affecting individuals' willingness to use shared autonomous vehicles.

Many studies have focused on the sociodemographic issues about the potential users of AVs and SAVs, and factors such as gender, age, annual-income and education have been repeatedly discussed and labeled as significant. Several studies suggest that males are more likely to accept new SAV technology than females, and women are more doubtful about the advantages of riding AVs and more concerned about AV technology safety and security (Wang & Akar, 2019; Wang & Zhao, 2019). In contrast, males and young adults are more inclined towards AVs because of their risk-taking nature (Hulse et al., 2018). Age has been mentioned as a significant predictor for using SAVs and can be interpreted to mean that younger people (18-34 years old) are more accepting to self-driving technology (Haboucha et al., 2017; Krueger et al., 2016; Lavieri et al., 2017; Zoellick et al., 2019). Highly educated and higher-income individuals are more inclined towards adopting AV technology (Shabanpour et al., 2018; Wang & Zhao, 2019) A comparison of generations reveals that millennials (those born between 1981 and 1998) seem to be more enthusiastic about self-driving vehicles than those born before mid-20th century (Lee et al., 2017). Potential AV and SAV users are usually well educated young people (Bansal & Kockelman, 2018; Schoettle & Sivak, 2015). Modelling Americans' autonomous vehicle preferences revealed that older adults and those without college degrees seem less willing to pay for dynamic ridesharing (Gurumurthy & Kockelman, 2020).

In-depth studies have explored the effects of individuals' perceptions towards the usage of SAVs. The literature discusses the significance of trust and risk (P. Liu, Q. Guo, et al., 2019; Zhang, 2019), technology-savvy attitude (Bansal et al., 2016; Lavieri et al., 2017), and the adoption of AVs and SAVs. After gathering data from people living near a university campus in Davis, California, Xing et al. (2020) investigated effects of attitude on the adoption of a shared level 4 autonomous shuttle. They discovered that trust influences willingness to use SAVs by moderating the effects associated with risk and convenience of using the technology. According to a study (Asgari & Jin, 2019) that looked at the aspects determining willingness to pay for autonomous vehicles, individuals would pay for autonomous vehicles provided they reduce cost and time. In addition, they suggested that individuals who enjoy driving were deemed least likely to adopt or to pay for AVs, while technology-savvy people more easily accept AV technology. A latent class analysis of people's attitudes in a residential area in Atlanta, Georgia (US) indicated that people preferred to live in communities with access to public transportation if the AVs reduce time and boost productivity (Lu et al., 2017).

Daily trip patterns can predict the extent to which an individual will exploit AV in the coming years, and understanding an individual's driving habits can be crucial in choosing the type of self-driving vehicle (Haboucha et al., 2017). According to a survey, 31% of those who use public transit daily or occasionally are optimistic about using autonomous buses, while 53% are less interested (Kassens-Noor et al., 2020). Public transit users are more inclined to share a ride in an SAV than those who do not use public transit, and similarly people who use services offered by transportation network companies (TNCs) are more likely to accept riding in SAVs than those who don't (Wang & Akar, 2019). Moreover, individuals with multimodal travel patterns are more interested in experiencing novel transportation modes (Krueger et al., 2016).

The aforementioned literature has been developed based on self-reported surveys of samples of populations without any experience riding in SAVs. Wu et al. (2020) used a stated preference survey to obtain data from 470 people to learn how they feel about autonomous cars. According to their results, individuals were apprehensive about the safety and legal implications of AV technology. Gurumurthy and Kockelman (2020) used a stated preference survey to develop two hurdle models to understand the WTP to share a ride and anonymize the location while using AVs. Moreover, past studies employed various methods and approaches to explore significant determinants of AV and SAV adoption. For instance, Zhang et al. (2015) used agent-based simulation to determine the impact of SAVs on parking demand in urban areas. They found SAVs reduce 90% of the parking demand of the individuals who use them. Another study by Liu et al. (2017) used agent-based modeling to determine the impact of SAVs in Austin with four different presumed fare rates per mile. According to their results, SAVs with lower fares per mile were more likely to be used in rural regions for long travel, whereas SAVs with higher fares per mile were more likely to be utilized in urban areas for short excursions. S. Wang et al. (2020) employed multinomial logit regression to determine the influence of behavioral factors on the using, sharing, and purchasing of AVs. They discovered that early technology adopters had a positive outlook, but risk-averse individuals had a negative attitude toward AVs.

(Zhu et al., 2020) developed a structural equation model (SEM) to determine the effects of mainstream media and social media on the desire to use AVs and SAVs. They determined that whereas mainstream media considerably increases the individuals' perceptions towards the danger of AVs, it also increases potential users' belief to master the AV technology. Social media reduces the perceived risk of AVs and strengthens subjective norms. Similarly, (Acheampong & Cugurullo, 2019) used SEM to develop four models using sociodemographic and behavioral determinants aimed to predict users' behavior towards 1) adopting AV, 2) adopting SAV, 3) AV as public transit mode, and 4) owning AV respectively. According to model 1 findings, females were more suspicious of the benefits of AVs and worried about their safety and security. Furthermore, they discovered that older adults had a negative perception of utilizing AV travel time for fun or productive activities compared to their younger counterparts. The findings of Models 2 and 3 indicated that those with pro-technology and pro-environment views were more likely to use SAVs and that younger people were more inclined to use AVs as a means of public transportation comparing to older adults. To understand millennials' adoption of AVs, (Manfreda et al., 2021) used SEM and found that perceived safety and benefits can significantly influence the adoption of AVs while technological and legal barriers might negatively influence AV adoption. In addition, using SEM (Yuen et al., 2021) demonstrated that perceived utility and accessibility significantly impact the behavioral intention to use AVs rather than income and education. However, even with simulations and consumer and preference surveys, it is difficult to truly understand the public's opinion of autonomous vehicles and impossible to predict how they will feel or what they will do in the future (Kim et al., 2020).

Although the reviewed literature gratefully can help in understanding the associations between individuals' attitudes, preferences, and adoption of self-driving services, how people will respond to SAVs on the road is still uncertain (Khan et al., 2022b). The literature research focuses mainly on potential riders with no actual ridership experience; it does not consider the riders' adoption and acceptance of self-driving shuttles. This study seeks to provide answers to the following questions: 1) What segments of population are frequent users of SAVs integrated into existing transportation infrastructure? 2) How does various factors like sociodemographic, vehicle ownership, RAPID usage, existing transportation services and service attributes impacts individual willingness to use SAVs using Structural Equation Modelling. 3) How do users' perception towards SAV service corresponds to the results of empirical studies about potential AV users?

5.4 Methodology

5.4.1 Case Study

In this study, we focused on a pilot project called RAPID (Rideshare, Automation, and Payment Integration Demonstration) that has been deployed in the City of Arlington, Texas, as of March 2021. The pilot extends from March 2021 through March 2022, and the city is partnering with Via Transportation, May Mobility, and the University of Texas at Arlington (UTA) to provide the service. The purpose of the grant is to integrate an on-demand AV transportation service with the existing transportation services and operate autonomous vehicles in downtown Arlington and the UTA campus area that provide free rides to students from Monday to Friday between 7:00 AM to 7:00 PM (City of Arlington, 2021a). The service is entirely on-demand and operates four Lexus hybrid vehicles and one Polaris GEM vehicle equipped to transport wheelchair users at speeds of up to 25 mph (City of Arlington, 2021b). The general population can use the service for the same price as the existing Via ridesharing service that has operated in the city since December 2017 (City of Arlington, 2019a). The wheelchair-accessible vehicle is available for people with disabilities to take advantage of the service. Figure 5-1 below shows the service area (boundary in blue color) of the Arlington RAPID project, which aims to provide accessible and affordable transportation to disadvantaged and underserved populations with limited access to private vehicles. As a result, the RAPID service operates only in certain parts of the city with a high poverty rate (39%) and households (11%) with no access to private vehicles (Etminani-Ghasrodashti et al., 2021b).

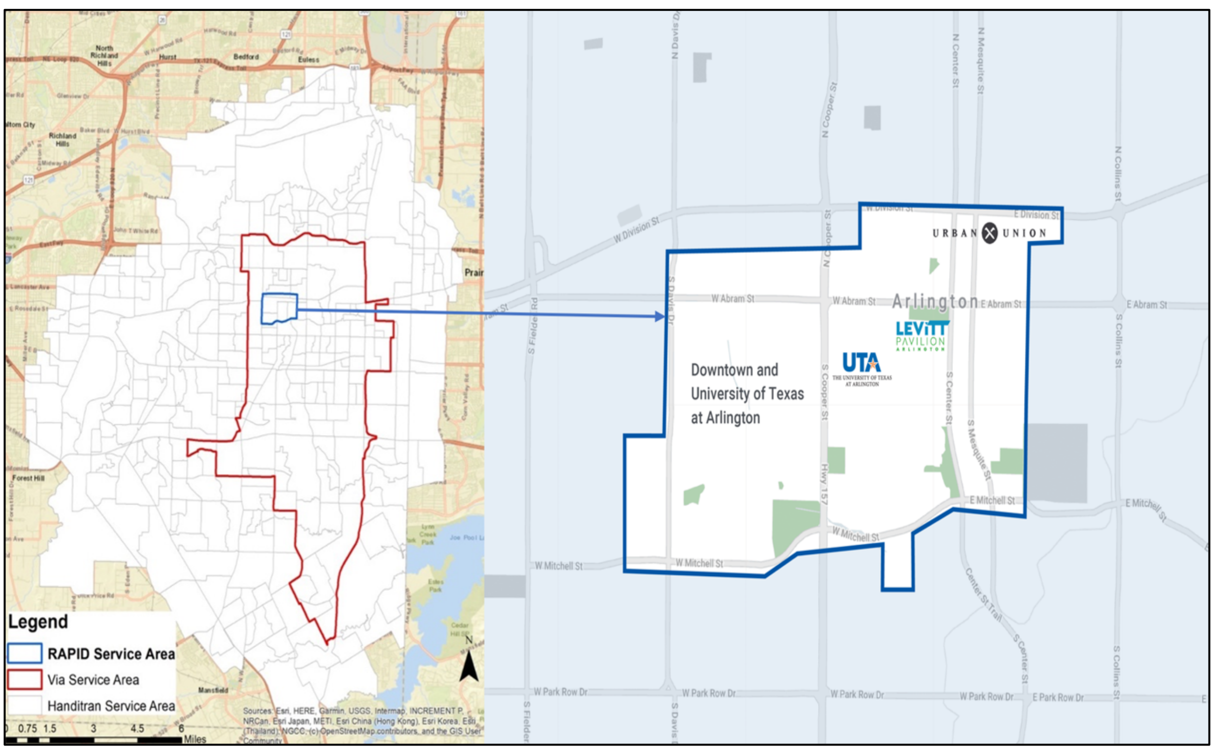

Figure 5-1 RAPID AV service area.

5.4.2 Data Collection

The RAPID SAV project research team developed a comprehensive survey that considered the results of focus group discussions organized in the pre-deployment phase of the project. We performed three focus group discussion studies with university students, the general public, and people with disabilities (Arif Khan et al., 2021a, 2021b; Etminani-Ghasrodashti et al., 2021a; Patel et al., 2021). Focus group studies provided valuable insights regarding the attitudes, and concerns of individuals about the proposed AV service (Etminani-Ghasrodashti et al., 2021b).

The primary aim of developing the survey was to collect data from the users and non-users of the RAPID SAV service. The study's target population was anyone above the age of 18 who works or lives in the city of Arlington. The survey was designed by the research team and was reviewed and approved by IRB at the University of Texas at Arlington. The questionnaire consisted of six parts related to 1) SAV usage and patterns of only users, 2) perception of SAV service by users, 3) users and non-users' attitudes towards SAV technology, 4) Individuals' travel patterns, 5) residential accessibility, and 6) sociodemographic characteristics. To get the maximum number of responses from potential and actual users of the AV service, the survey was distributed via the QuestionPro platform and by sharing the survey URL through flyers and emails to the UTA students, faculty, staff, and the general community. Via Transportation also assisted in distributing the survey link among the RAPID users through their app, while the City of Arlington shared the survey link on their official website. Among the 3,803 people who viewed the survey, 690 people responded to it, and 250 respondents (about 36%) completed the online questionnaire. About 440 people left the survey without completing it. One possible explanation for the high survey dropping rate can the possibility of ending the survey by respondents without being obligated to answer all questions. The average time taken to complete the survey was approximately 5 minutes. This study was performed nine months after the project began, which meant that some community segments were unfamiliar with the service; even so, the response rate was very low. This study is developed based on the SAV users and non-users data and information to answer the research questions.

5.4.3 Compilation of Dataset

The key variables of this study were developed by reviewing the SAV literature and results from focus group studies in the case study. Moreover, perception towards SAVs have been identified as dependent variable that can be affected by sociodemographic of the participants.

5.4.3.1 RAPID Users and Non-Users

Respondents were asked to identify if they had used the RAPID service in the city of Arlington to classify the sample population as SAV users and non-users. About 85 (34%) individuals had used the RAPID SAVs nine months after the service demonstration, and 165 (66%) individuals had not used it. Since the RAPID service area is limited around the UTA campus, a majority (90.6%) of the RAPID service users were students.

5.4.3.2 RAPID Usage

Table 5-1 Users' frequency of using the RAPID AV service

RAPID Usage	Frequency	Percentage
One time	14	16.5
Two times	8	9.4
Three to four times	20	23.5
Five to six times	6	7.1
More than six times	37	43.5
Total	85	100

Moreover, to understand RAPID acceptance among the sample population, we asked the users how many times they rode the RAPID service with the following options (one time, two times, three to four times, five to six times, and more than six times). Among the 85 respondents who used the RAPID service, about 74% of them used it more than two times, as shown in Table 5-1.

5.4.3.3 RAPID Service Attributes: Comfort and Safety

Reviewing the literature indicates that the general public attitude could have a significant effect on the adoption of AVs and SAVs (Asgari & Jin, 2019; Lavieri et al., 2017; P. Liu, Q. Guo, et al., 2019; Xing et al., 2020; Zhang, 2019). Consequently, six individual statements were included in the survey to measure individual perceptions towards the RAPID SAV service attributes. These statements were related to 1) SAV features like speed, seating comfort, and climate control and 2) AV service attributes such as capability to communicate with other cars on the road, sharing the ride with other passengers, and cleaning protocols.

Table 5-2 Rotated Component Matrix for Perceptions Towards RAPID Service

Please rate your experience riding RAPID in the following areas (From 1: very poor to 5: excellent)	**Factor Loadings**
	Comfort & Safety
1. Comfort of seats and climate control	0.812
2. Feeling of safety due to presence of onboard human attendant	0.701
3. Ride comfort due to the vehicle traveling at a reasonable speed	0.837
4. Feeling of safety over the AV's ability to communicate with other vehicles on the road	0.886
5. Feeling of safety related to sharing the RAPID ride with other passengers	0.763
6. Feeling of comfort due to cleaning protocols while sharing the RAPID ride with other passengers	0.810
% Of Variance	**64.60%**

The respondents rated their perception about RAPID service attributes on a 5-point Likert scale (where 1=Very Poor and 5= Excellent). Furthermore, we performed factor analysis using the SPSS

AMOS V.28 software to decrease variables and obtain latent factors. All these statements were factor analysed using Principal Component Analysis (PCA) and Varimax (orthogonal) rotation. The analysis resulted in a single component explaining 64.60% variance of the entire set of variables with a Kaiser Mayer Olkin (KMO) = 0.836. This factor was labelled as "Comfort and Safety" as shown in Table 5-2.

5.4.3.4 Trip Purpose

In order to understand the travel patterns of RAPID users, participants were asked about their purpose for using the RAPID service. Their responses were given in six categories (work, school, shopping, medical, social, and recreational, and others). Results indicated that school (42.61%), work (19.32%), and shopping (18.75) were the top three purposes for using the RAPID service, as shown in Table 5-3.

Table 5-3 Trip purpose for using RAPID (More than one response)

Trip Purpose	Frequency	Percentage
Work	34	19.32
School	75	42.61
Shopping	33	18.75
Medical	8	4.55
Social and recreational	22	12.5
Others	4	2.27
Total	176	100

Note: The percentage are provided based on the total number of counts

5.4.3.5 Willingness to Use SAV's

Moreover, to understand the willingness to ride SAV's, users were asked about the likelihood of riding the RAPID service in the future if it continues to provide service in Arlington. The responses were requested on a five-point Likert scale (where 1= "very unlikely, 2= "unlikely", 3= "neutral", 4= "agree", and 5= "very likely").

5.4.3.6 Existing Modes of Transportation

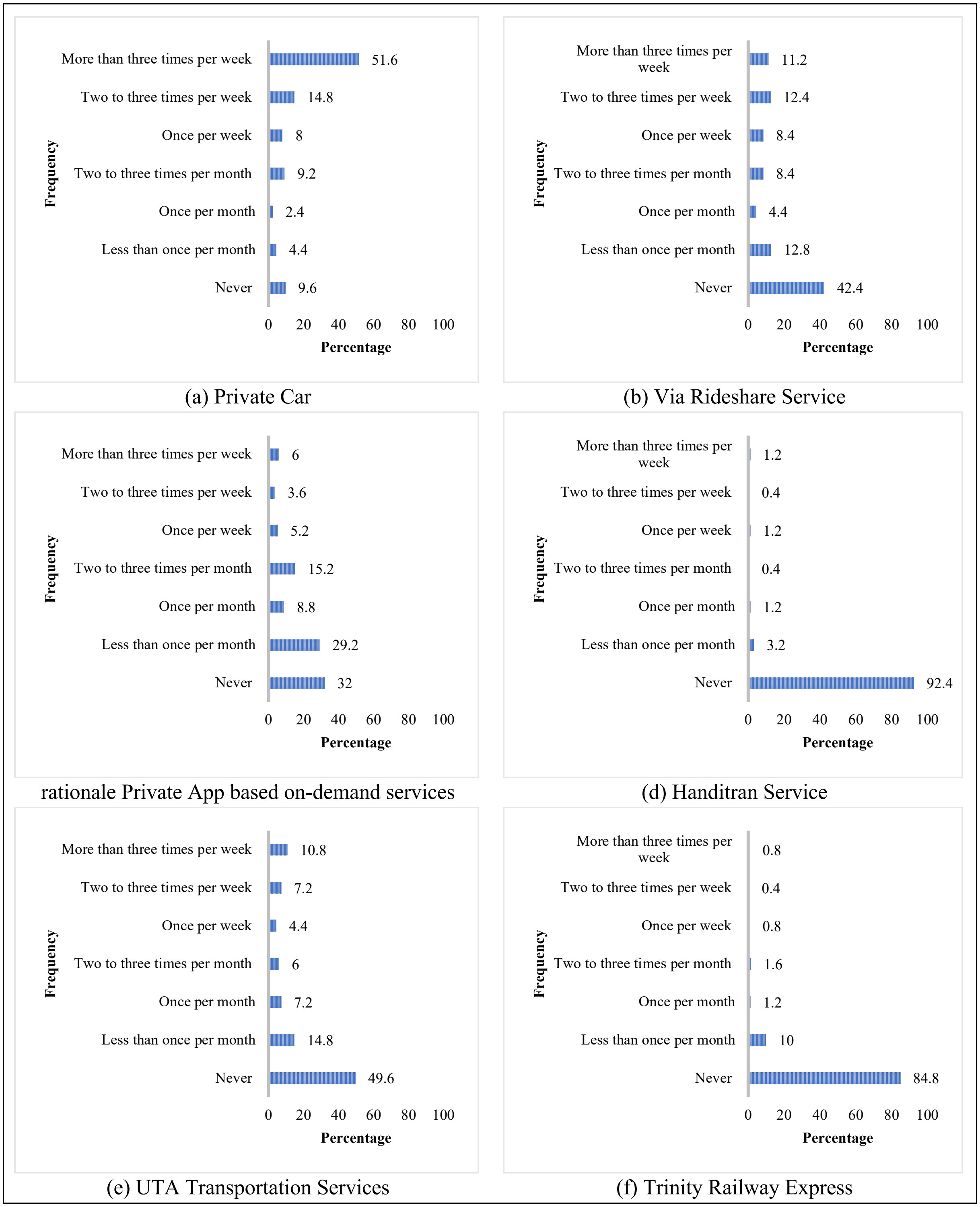

Figure 5-2 Participant's Using Existing Modes of Transportation

In past, studies have emphasized the impacts of individuals' travel modes and daily travel patterns on the adoption of SAVs (Krueger et al., 2016; Wang & Akar, 2019). We asked respondents how often they used existing modes of transportation like Via Ridesharing Services, Private On-Demand Transportation Services (Uber and Lyft), Handitran Service, UTA Transportation Services, and Trinity Rail Express. The responses were requested on a 7-point scale (where 1= "never", 2= "less than once per month", 3= "once per month", 4= "two to three times per month", 5= "once per week", 6= "two to three times per week" and 7= "more than three times per week". Results indicated that among the 250 participants who responded, about half of the respondents (51.6%, n=129) were frequent users of private transportation (cars). About a third (32%, n=80) of the respondents use the Via Ridesharing service at least once a week. However, a very low number of respondents (14.8%, n=37) use the private app-based on-demand services (Uber and Lyft) at least once a week. Similarly, about one fifth (22.4%, n=56) of the respondents used the UTA shuttle service at least once a week. A majority of the participants (92.4%, n=231) did not use the Handitran service (paratransit service in Arlington), which provides transportation to eligible seniors and people with disabilities. In addition, (84.8%, n=212) of the respondents did not use the Trinity Rail Express service, which connects Arlington with the other nearby cities, as shown in Figure 5-2.

Furthermore, to categorize the respondents based on their travel patterns, we performed a PCA on all the five transportation options described above. However, the results were not satisfactory, and the descriptive statistics indicated that a majority, about 80% and 94% of the participants, never used the Trinity Rail Express and Handitran Service. As a result, we excluded these variables and factor analysed the other three variables using PCA and Varimax rotation. The analysis yielded one factor labeled Existing Transportation Services explaining 59.74% variance of the entire set of variables with KMO = 0.582. The factor loadings have been provided in Table 5-4 below.

Table 5-4 Rotated Component Matrix for Existing Modes of Transportation

How often do you usually use the following modes of transport? (From 1: never to 7: more than three times per week)	**Factor Loadings**
	Existing Transportation Services
▪ Via Rideshare service	0.862
▪ UTA transportation services	0.702
▪ Private app-based services such as Uber/Lyft	0.746
% of Variance	**59.74%**

5.4.3.7 Sociodemographic

Finally, we collected information related to sociodemographic factors of the survey participants. The last section in the survey asked the survey respondents about their sociodemographic information like gender, age, race, ethnicity, educational background, employment status, household income, vehicle ownership. Table 5-5 shows the descriptive statistics of the survey participants. The results show that half (50%, n=125) of the participants were male, and 45.6% (n=114) were females, indicating a relatively proportional distribution. Most of the participants (89.6%, n=224) were young (18-34 years), and almost half of them (44.4%, n=111) were highly educated individuals. The majority of the population were Asian (47.6%, n=119) individuals, followed by White (26.8%, n=67), African American (15.6%, n=39), and others (8%, n=20), respectively. More than half of them (51.6%, n=129) had annual household income under $20,000. More than a quarter (27.6%) of the population had no access to a private vehicle, while the other two-third of the population at least had one private vehicle in their household. The sample distribution is in line with the targeted population of the RAPID Arlington project, which was students and people from lower-income households with limited mobility working or living in the city of Arlington.

Table 5-5 Sociodemographic of Survey Participants

Sociodemographic	Description of Variable	Frequency	Percentage
Gender	Male	125	50
	Female	114	45.6
	Other	3	1.2
	Prefer not to answer	8	3.2
Age	18-24	157	62.8
	25-34	67	26.8
	35-44	11	4.4
	45-54	9	3.6
	55-64	3	1.2
	65 and above	3	1.2
Race	American Indian or Alaskan Native	5	2
	Asian	119	47.6
	Black or African American	39	15.6
	White	67	26.8
	Other	20	8
Ethnicity	Hispanic	41	16.5
	Non-Hispanic	208	83.5
	Did not answer	1	0.4
Education	Some grade/high school	2	0.8
	High school/GED	33	13.2
	Some college/technical school	60	24
	Associate degree	39	15.6
	Bachelor’s degree	48	19.2
	Graduate or professional degree	63	25.2
	Prefer not to answer	5	2
Annual Household Income	Less than $20,000	129	51.6
	$20,000 - $34,999	44	17.6
	$35,000 - $49,999	27	10.8
	$50,000 - $74,999	21	8.4
	$75,000 - $99,999	13	5.2
	$100,000 or more	16	6.4
Vehicle Ownership	No vehicle	69	27.6
	One vehicle	90	36
	Two vehicles	59	23.6
	Three or more vehicles	32	12.8

5.4.4 Conceptual Framework for the study

The previous studies developed models related to AVs and SAVs adoption by exploring sociodemographic variables and individual attitudes. However, due to very few autonomous vehicles pilot services and minimal access to ridership data, the majority of the past studies focused on the data collected from potential users and non-users of AVs instead of the actual users and used simulations or consumer and preference surveys to predict general public behaviour towards autonomous vehicles. We developed our conceptual framework considering the actual SAV users and factors affecting the adoption of emerging technology, as shown in Figure 5-3 below.

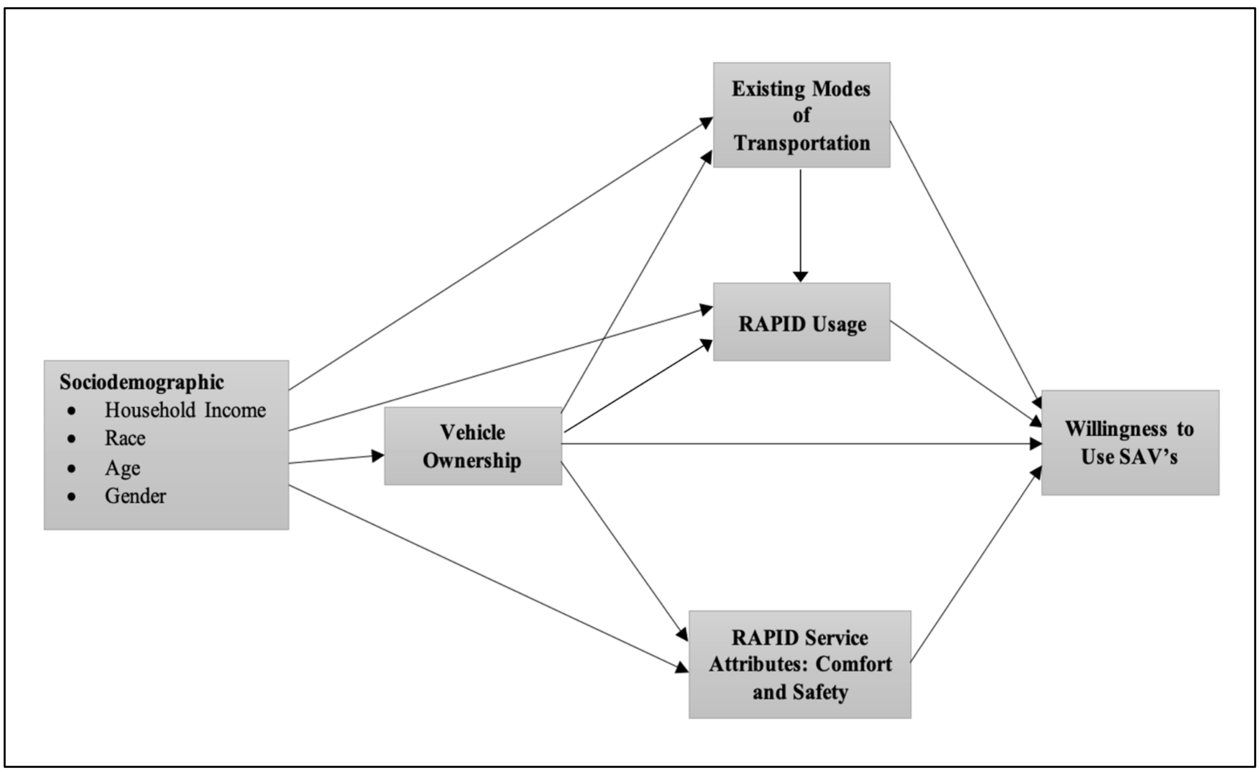

Figure 5-3 Conceptual model for the study

Literature suggests that factors like trust and risk play a crucial role in AV adoption (Bansal et al., 2016; Lavieri et al., 2017; P. Liu, Q. Guo, et al., 2019; Zhang, 2019). For this study, our conceptual model assumes that an individual's perception towards RAPID service attributes in terms of comfort and safety of AVs would play a significant role in predicting willingness to use the SAVs as an on-demand transportation mode in the future.

Since Arlington does not have a mass transportation system, we developed our conceptual model considering that the existing modes of transportation would directly impact the users' willingness to use SAVs.

We also assume that SAV trip frequency or RAPID usage might influence users' perception of the SAVs by assuring safe travel and increasing the belief in the AV technology. Vehicle ownership has been proved to be a factor that can affect individuals' travel behaviour and acceptance of emerging mobility modes (Menon et al., 2019). Accordingly, our model considers the direct effect of vehicle ownership on willingness to use SAVs.

Past studies have identified the impact of sociodemographic factors on AV adoption (Zoellick et al., 2019). In our model, we assume that sociodemographic factors including household income and gender can indirectly influence the willingness to use SAVs. It means that vehicle ownership, RAPID usage, existing modes of transportation, and perception of RAPID service attributes: comfort and safety can mediate the role of sociodemographic variables on the willingness to use SAVs in the future.

We assume that vehicle ownership can influence individuals' RAPID usage and RAPID service attributes. We predict that people with less access to a vehicle use the existing SAV service less frequently. In addition, possessing a vehicle can influence the perception of users regarding the comfort and safety of the SAVs after using this service.

The conceptual model of the present study counts for direct effects and indirect effects of key variables on willingness to use SAVs. Moreover, the model evaluates the interrelations between key variables. Accordingly, we performed structural equation modelling (SEM), a technique useful for modelling and testing complex multi-dimensional concurrent relationships between independent and dependent variables using SPSS AMOS V28 software. Furthermore, we used the maximum likelihood estimation technique to obtain model parameters.

In our model, willingness to use SAVs is the final endogenous variable affected by the key variables. Willingness to use SAV was identified as a five-category ordinal measure that was evaluated ascendingly. As a result, our model treated it as a continuous dependent variable (Rhemtulla et al., 2012). Existing modes of transportation and RAPID service attributes (comfort and safety) were extracted from the factor analysis and incorporated as continuous variables in the model. RAPID usage, vehicle ownership, household income, and age were all ordinal variables with more than five categories in our model, and they were also handled as continuous variables. Race was recoded as a binary variable that included White (0) and non-White (1) individuals. For example, if respondents selected White as their race, their response was recoded as (0), while responses to other categories such as African American, Asian, American native, and others were recoded as (1). Gender was also recorded as a binary variable, with males (0) and females (1). As a result, those who chose males had their responses recoded to (0), while those who chose females as their gender in the survey had their responses recoded to (1).

5.5 Results

The relationships in our hypothesized conceptual model were evaluated empirically. However, the actual structural model constructs were a little different from the conceptual framework suggested earlier. We made some changes to our conceptual model to improve the validity of the results. We disregarded analyzing two relationships 1) between race and RAPID service attributes (Comfort and Safety) and 2) between gender and vehicle ownership since they were not statistically significant to improve the model fitness results.

Table 5-6 PATH Coefficient Estimates for Direct Effects of the Key Variables

Key Variables		Sociodemographic & Travel Attributes	Estimate	P Value
Vehicle Ownership	←	Household Income	0.27	0.00*
Vehicle Ownership	←	Race (Non-White)	-0.30	0.03*
Vehicle Ownership	←	Age (under 25 years)	0.15	0.46
Existing Modes of Transportation	←	Household Income	-0.02	0.69
Existing Modes of Transportation	←	Race (Non-White)	0.27	0.03*
Existing Modes of Transportation	←	Age (under 25 years)	0.54	0.01*
Existing Modes of Transportation	←	Gender (Female)	-0.07	0.54
Existing Modes of Transportation	←	Vehicle Ownership	-0.41	0.00*
RAPID Usage	←	Household Income	-0.06	0.58
RAPID Usage	←	Race (Non-White)	1.02	0.00*
RAPID Usage	←	Age (under 25 years)	1.08	0.05*
RAPID Usage	←	Gender (Female)	0.68	0.02*
Comfort and Safety	←	Household Income	-0.03	0.64
Comfort and Safety	←	Age (under 25 years)	0.32	0.38
Comfort and Safety	←	Gender (Female)	-0.28	0.15
Comfort and Safety	←	Vehicle Ownership	0.02	0.88
RAPID Usage	←	Existing Modes of Transportation	0.31	0.08*
RAPID Usage	←	Vehicle Ownership	0.15	0.43
Willingness to use SAVs	←	RAPID Usage	0.09	0.01*
Willingness to use SAVs	←	Existing Modes of Transportation	0.08	0.15
Willingness to use SAVs	←	Comfort and Safety	0.33	0.00*
Willingness to use SAVs	←	Vehicle Ownership	-0.02	0.69
Model Fit Indices	**$\chi 2$/ df = 2.9**	**RMSEA = 0.09**	**CFI = 0.96**	

Note: * Significance at α = 0.05

We checked three model fitness indices to evaluate the good fit for the hypothesized model with observed data. We first measured the ratio of chi-square to the degree of freedom (χ^2/df) which suggests if the data fits the model was evaluated. The value of χ^2/df was (2.9), which is under the recommended value of less than 5 (Mokhtarian & Ory, 2008). Secondly, we observed the Root Mean Square Error of Approximation which indicates the approximation error per model degree of freedom. The RMSEA value for the hypothesized model was (0.09), which is near to the acceptable value between 0.05 – 0.08 for a model to be a good fit (Hu & Bentler, 1999). Since the sample size is small, Comparative Fit Index (CFI) was checked for model fitness as it performs well with small sample size. The value of CFI was (0.96), which satisfies the recommended criteria of (> 0.95) for a good model fit (Hooper et al., 2008; McDonald, 1989; Weston & Gore Jr, 2006) as shown in Table 5-6 below.

5.5.1 Determinant Factors for Willingness to Use SAVs.

The results indicate that the RAPID usage directly impacts users' willingness to ride SAVs in the future. It means frequent users of the RAPID service were more optimistic about using a similar service in the future. Moreover, the RAPID service attributes (Comfort and Safety) also significantly impacts users willingness to ride SAVs in future. This result indicated that people who were comfortable and felt safe while riding the RAPID AVs were positive about using SAVs in future.

We also hypothesized the association between vehicle ownership and willingness to use SAVs. Although the results were not significant, the coefficient was negative (as expected), indicating that people using private vehicles for transportation were less likely to use SAVs. Similarly, the relationship between existing modes of transportation and willingness to use SAVs was not statistically significant. However, the coefficient was positive, suggesting that people using shared and on-demand transportation services are more inclined towards using SAVs in the future.

5.5.2 Effects from Sociodemographic Factors

Results indicated that females were less likely to ride the RAPID service than their male counterparts frequently. Furthermore, age had a significant positive relationship with RAPID ridership, implying that young adults were more likely to ride the RAPID service frequently. Furthermore, the non-white population had a significant positive relationship with RAPID usage, implying that the non-white population might ride the RAPID service more frequently than the white population.

Similarly, Other races than White (non-White races) showed a significant positive association with the existing modes of transportation, suggesting non-White respondents were more likely to use existing app-based on-demand services compared to respondents whose race was reported as White. Moreover, respondents under the age of 25 years had a significant relationship with the existing modes of transportation. These results were expected as the RAPID service area was limited to the UTA campus and Downtown Arlington and young international students living on-campus were most likely to exploit these services to their advantage. Along these lines, results suggested that the non-White population had a significant negative relationship with vehicle ownership. It means that the non-white population were less likely to own a private vehicle.

5.5.3 Effects from Vehicle Ownership

Vehicle ownership had a negative association with existing modes of transportation, suggesting vehicle ownership reduces the likelihood of using existing app-based on-demand transportation services and increases the possibility of using private vehicles. Similarly, there was a positive relationship between household income and vehicle ownership, implying that people with higher household incomes were more likely to possess a car.

5.5.4 Effects from Existing Modes of Transportation

We found a positive relationship between RAPID usage and existing modes of transportation. This means individuals using the existing app-based on-demand transportation services or university transportation services were more likely to use the RAPID AV service. Since the RAPID service is centered around the university campus area and downtown Arlington, a majority of its' users are students with no or limited access to a private vehicle. As a result, these individuals are more likely to depend on the existing app-based on-demand services like Via and the university transportation for their daily transportation.

5.6 Discussion and Conclusion

This study investigates the AV user and non-users' willingness to use the Shared Autonomous Vehicle service using a survey instrument developed to take input from RAPID pilot SAV riders comprising students and the general public living and working in the city of Arlington, Texas. Apart from the existing research, we conceptualized our study model based on actual SAV ridership data considering sociodemographic (age, gender, race, and household income), service attributes, vehicle ownership, SAV (RAPID) usage, and existing modes of transportation and explored the relationship among these factors. Considering the RAPID SAV service is operated in a limited-service area around the UTA campus and downtown Arlington the descriptive analysis of the survey participants suggested that most current users of this pilot service were young Asian individuals and students. Most of them were from lower-income households with limited or no access to private transportation. Consequently, most of them were frequent users of transportation services available in the city like Via Ridesharing service and the private on-demand services (Uber and Lyft). These results imply that the RAPID project is achieving its goals of providing transportation services to young individuals from lower-income households with no access to private vehicles and integrating Level 4 AVs into the its transportation infrastructure. Similarly, the pricing policies of the future SAV services should be tailored for the general population who do not own a car and are from low-income households considering SAV technology can improve transportation equity and affordability. Furthermore, local governments and authorities can establish and execute strategies to boost the economic efficiency of future SAV services, such as subsidizing SAV services for low-income groups.

We used SEM to identify impacts of the interplay of relationships between variables like sociodemographic, vehicle ownership, and RAPID usage of usual transportation services and RAPID service attributes (comfort and safety). Results indicated that the frequency of using the SAV's (RAPID usage) significantly impacts willingness to use SAVs in the future. This finding implies that an increase in SAV usage develops the trust in AV technology, thereby making it convenient or more accessible for individuals to use the SAVs as a usual transportation mode. Moreover, existing research (P Liu et al., 2019b) also confirms that trust directly impacts while perceived risk indirectly impacts the acceptance of autonomous driving. To increase the frequency of using SAVs, the policymakers should provide promotions and lucrative offers for frequent riders in order to make them familiar with the technology in order for them to use it safely.

Furthermore, we found that RAPID usage positively mediates the effects of the race (non-white population) on the willingness to use SAVs in the future. Results also indicate that the non-white population was less likely to use or own private vehicles. This finding can be supported by our previous result indicating that the non-White population (especially international students with low household incomes) living on campus are more likely to use university transportation or app-based on-demand services because they have limited access to private vehicles. The existing research supports this as people of color are more inclined to use the SAV services (Xing et al., 2020). Another possible explanation for this is the prevailing idea of automobility (utilization of automobiles as significant means of transportation) in North America, which prevents private car users (white population) from using SAV's (Haboucha et al., 2017; Mohammadzadeh, 2021; Moody & Zhao, 2020). Transit agencies planning to integrate SAVs with existing modes of transportation should emphasize their focus in areas having non-white population. Similarly, we found that young individuals between 18-24 years old are inclined towards using SAVs. This finding is consistent with the previous study (Wang and Akar, 2019), indicating younger individuals are more inclined to adopt AV technology than older people. However, due to disabilities and health issues, older adults are another potential population that needs access to mobility alternatives other than private vehicles. As a result, to successfully introduce SAVs to the market, policy interventions may need to be required to influence older individuals' willingness to adopt AV technology. In addition, we discovered that females are more prone to use SAVs than males. These findings imply that women prefer to use SAVs, as they do not interact with drivers. This result contradicts previous findings suggesting females are more likely to travel using AVs than SAVs (Wang & Akar, 2019).

People from higher-income households were more likely to have access to a private vehicle. Similarly, our findings show that having a car had a detrimental influence on using existing modes of transportation, meaning that those with private vehicles were less inclined to use transportation services available in the area. These results support the finding from previous research by (Krueger et al., 2016), suggesting that people from lower-income households have very limited mobility options and are more likely to use existing modes of transportation.

Although multiple pilot demonstrations have been deployed in some regions of the United States, very little is known about individuals' acceptance of SAVs. SAV pilots are an excellent opportunity for researchers and policymakers to learn changes in user travel patterns after integrating autonomous vehicles into existing transportation infrastructure. Understanding the factors that impact users' willingness to use SAVs in the future can help policymakers and transportation planners to develop policies that help in the smooth transition of traditional transportation systems to AV-based transportation. However, to make users more familiar with AV technology, there is a dire need for pilot developments throughout the country. People can experience the emerging AV technology through these demonstrations, which will gradually increase their trust towards the technology and help the entities to roll out the technology universally. In order to increase SAV adoption, the government and automobile industry should carefully evaluate public concerns and opinions towards AV technology and promote public awareness about SAV services. Pilot SAV implementations can provide empirical evidence to demonstrate the reliability of the technology and increase public trust in the technology's safety through testing and riding the AVs on actual roads.

This study provides insights into the determinants impacting the individual's willingness to use SAVs. However, this study has a few limitations that stem from large amount of data obtained from university students. First, because the RAPID SAV service boundary has been developed around the university campus, most riders were university students, and the general public had limited accessibility to the SAV service. Second, at the time of this study, the RAPID service provided free rides to students, which encouraged students to use the service more frequently than the general public. Third, the survey was distributed through online channels; hence, only people who visited the specified websites had the opportunity to participate in the online survey. As a result, the findings of this study are constrained by the homogeneity in the sample population with a majority of them being university students. It is not surprising since university students usually have limited access to a private vehicle, and lower income as compared to other segments of the community. Accordingly, it is rationale that students would benefit from the free rides available to them. With that said there is a need to conduct further research to understand how members of the general public who have to pay for the service adopt SAVs in the future. Moreover, it is worth noting that employing a sample size from diverse categories of SAV users, may result in findings different from the present study. For instance, our findings indicated that females are more prone to use SAVs than males while past research suggested that males are more likely to use AVs and females are more skeptical about the advantages of riding AVs and are concerned about AV safety and security (Hulse et al., 2018; Wang & Akar, 2019; Wang & Zhao, 2019). Moreover, this research was conducted through a cross-sectional design using a self-reported questionnaire. Since the study was developed during the ongoing pilot demonstration, people's perception of SAVs is not likely to be anchored. As more people experience the technology under multiple scenarios and the emerging AV technology unfolds, more significant determinants related to the SAV adoption might be discovered. Further research can be developed based on the findings of this study to identify factors associated with the SAV service in different regions to generalize the findings.

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CHAPTER 6

IDENTIFYING INDIVIDUALS' PERCEPTIONS, ATTITUDES, PREFERENCES, AND CONCERNS OF SHARED AUTONOMOUS VEHICLES: DURING- AND POST-IMPLEMENTATION EVIDENCE

6.1 Abstract

SAVs (shared autonomous vehicles) have the potential to improve the efficiency, mobility, safety, and affordability of transportation systems; however, consumers will determine whether they can be successfully integrated into the current systems. This study aims to identify the perceptions, attitudes, preferences, and concerns of those who have and have not taken advantage of the AV technology by sharing the results of a pilot project and providing the responses of those who were exposed to a self-driving technology demonstration. A two-step approach was employed for this study: (a) quantitative analysis of a self-reported survey of SAV users and non-users who experienced SAVs on the road, and (b) a qualitative study of interviews conducted during the post-implementation phase of the project. The results from an ordinal logistic regression of a self-reported survey showed that the ease of using SAVs because of not having to worry about parking is positively associated with individuals' willingness to use and adopt them in the future. In contrast, however, concerns about possible confusion arising between human drivers and SAVs on the street decrease willingness to use SAVs. A qualitative analysis of interviews conducted on this subject indicated that waiting time, pick-up and drop-off locations, and the ability to make tight turns in intersections are the three major concerns. Expectations are high, as potential riders anticipate that SAVs will be more cost efficient, safer, and more environmentally friendly than owner-operated vehicles, as well as able to enhance transportation equity. This study provides insights into the perceptions and attitudes of SAV users and non-users and identifies strategies for

successfully integrating an SAV service with an existing on-demand ridesharing service, thereby enhancing future acceptance of the technology.

6.2 Introduction

Technology advances have revolutionized the automobile industry over the last few decades, and autonomous vehicles (AVs) are among the most essential and innovative technologies in the industry (Hilgarter & Granig, 2020). They, along with revolutionary technology such as electric vehicles, on-demand mobility services, micro-mobility, demand-responsive transit (DRT), and mobility as a service (MasS), will drive the future of transportation mobility (Butler et al., 2021; Khan et al., 2022d) and are expected to fundamentally change the transportation system in terms of user experience, travel choice, and business models (Chan, 2017). The predominant mode of travel in the United States is a personal vehicle or light truck, and at least 24% of households now have three or more in their possession (Center for Sustainable Systems, 2021). The number of registered automobiles climbed from around 250 million to 276 million between 2010 to 2020 (Bureau of Transportation Statistics, 2022b), causing increased traffic congestion, greenhouse gas emissions, and fatal accidents (Hilgarter & Granig, 2020), and there were 5.25 million crashes in 2020 that resulted in 2.28 million minor injuries and 38,824 fatalities (Bureau of Transportation Statistics, 2022a).

Autonomous vehicles are predicted to have a significant impact on transportation systems by preventing fatal crashes, decreasing emissions, reducing traffic, boosting mobility for transportation-disadvantaged populations (elderly and disabled), and improving fuel efficiency (Fagnant & Kockelman, 2015; Khan et al., 2022a). The emergence of autonomous vehicles could be genuinely transformative in terms of vehicle ownership, residential spatial patterns, and vehicle miles traveled (VMT) (Zmud & Sener, 2017). Researchers predict that AV technology will be developed and operational by 2030 and that more than 90% of the existing vehicle fleet by 2055 will be autonomous vehicles (Greenblatt & Shaheen, 2015). The Society of Automotive Engineers (SAE) has broadly categorized AVs into six categories, ranging from Level 0 (no automation) to Level 5 (complete automation) (Society of Automotive Engineers, 2021). Recently in the United States, 17 Level 4 SAV pilot projects were deployed in eight states: 53% were in the testing phase with pre-selected passengers, and 47% provided rides for the general public (Stocker & Shaheen, 2019). However, because self-driving vehicles are not currently on roads, except for a few AV testing and pilot projects, it is difficult to forecast the effects of autonomous vehicles with any certainty (Zmud & Sener, 2017).

Earlier studies explored factors affecting the adoption of AVs, with most of them focused on sociodemographic variables like gender, age, income, and education (Haboucha et al., 2017; Hulse et al., 2018; Krueger et al., 2016; Lavieri et al., 2017; Schoettle & Sivak, 2015; Shabanpour et al., 2018; Wang & Akar, 2019; Wang & Zhao, 2019; Zoellick et al., 2019). Most researchers consider age as a key determinant in the adoption of SAVs and have found that young people are more receptive of the technology (Haboucha et al., 2017; Khan et al., 2022c, 2022e; Krueger et al., 2016; Lavieri et al., 2017; Zoellick et al., 2019). According to Wang & Akar (2019) and Wang & Zhao (2019) women are more concerned about the safety and security issues and are less likely to adopt the technology than men.

Researchers have also emphasized the impacts of personal attitude on the adoption of autonomous vehicles (Asgari & Jin, 2019; Bansal et al., 2016; P. Liu, R. Yang, et al., 2019; Zhang, 2019). Asgari & Jin (2019) studied what makes people willing to pay for autonomous vehicles and found that it was the ability to save time and money. Past studies used a qualitative approach by conducting multiple focus groups to understand the potential users concerns, preferences, and expectations of future SAV service (Etminani-Ghasrodashti et al., 2021a, 2021b; Weinreich, et al., 2021; Patel et al., 2021). Some researchers have focused on the importance of service attributes, espousing that cost, travel and waiting time, safety and mobility are vital to the acceptance of SAVs (Jing et al., 2020; Krueger et al., 2016). Studies used the quantitative approach to explore the acceptance of autonomous vehicles by employing stated preference surveys (Gurumurthy & Kockelman, 2020; Kyriakidis et al., 2015; Penmetsa et al., 2019; Schoettle & Sivak, 2015; Wu et al., 2020); most of them focused on individuals with no AV ridership experience.

Few studies have explored the perceptions and attitudes of individuals who have experienced AV technology first-hand (Hilgarter & Granig, 2020; Nordhoff et al., 2019; Salonen & Haavisto, 2019; Schoettle & Sivak, 2015). (Hilgarter & Granig, 2020) investigated the perceptions of rural and urban residents who had ridden in a Level 3 autonomous shuttle and found that those from rural communities were more enthusiastic about it than those from urban areas. They also found that the SAV users regarded them as an alternate form of transportation rather than as a replacement for existing modes of transportation. Nordhoff et al. (2019) found that SAV users were open to using autonomous shuttles as a feeder service for public transit, and Salonen & Haavisto (2019) found that people feel safe while riding the autonomous shuttle bus but are less accepting of accidents caused by AVs than accidents caused by human drivers. Earlier studies employed structural equation modeling (SEM) using real ridership data and found that SAV service attributes, existing modes of transportation and sociodemographic characteristics significantly impact users willingness to ride SAVs in the future (Etminani-Ghasrodashti et al., 2022a; Patel et al., 2022b, 2022c, 2022d). The successful integration of SAVs into existing transportation systems is dependent on the attitude and perception of potential users towards these services.

Although past studies provide information on individual preferences, and concerns of AV technology and identify the significant determinants impacting SAV adoption, some research questions are still unanswered. The literature lacks empirical assessments of riders perceptions of SAV service attributes and features and their attitude towards AV technology development that will affect SAV adoption in the future because it mostly focuses on potential riders without actual ridership experience. This study investigates individual attitudes toward AV technology through an ordinal logistic regression model, using survey data collected from users and non-users of a pilot SAV service. Moreover, this study provides insights into users and potential users perceptions and attitudes using qualitative data derived from personal interviews with 11 individuals. These interviews were designed to answer the following questions during the post-implementation phase of the project: a) How do SAV riders respond to the integration of SAVs and the existing transportation systems? b) How will individual attitudes impact the adoption of SAVs? and c) What are the preferences and concerns of users and potential users about accepting SAVs?

6.3 Research Methodology

6.3.1 Case Study

Arlington RAPID (Rideshare, Automation, and Payment Integration Demonstration) is a pilot project in the City of Arlington, Texas that operated from March 2021 through March 2022. It was a collaboration between the City of Arlington, Via Transportation, May Mobility, and the University of Texas at Arlington (UTA) that integrated an AV transportation service with an existing on-demand ridesharing service. Under this project, autonomous vehicles provided service to downtown Arlington and on the university campus, giving free rides to students from 7:00 AM to 7:00 PM Monday through Friday (City of Arlington, 2021b). The service was comprised of four Lexus hybrid cars and one Polaris GEM vehicle that was built to carry wheelchair users at speeds up to 25 mph. The general public was welcome to ride for the same price as the city's existing Via ridesharing service, which began operation in December 2017 (City of Arlington, 2019a). In Figure 6-1 below, the service area of the RAPID project is outlined in blue.

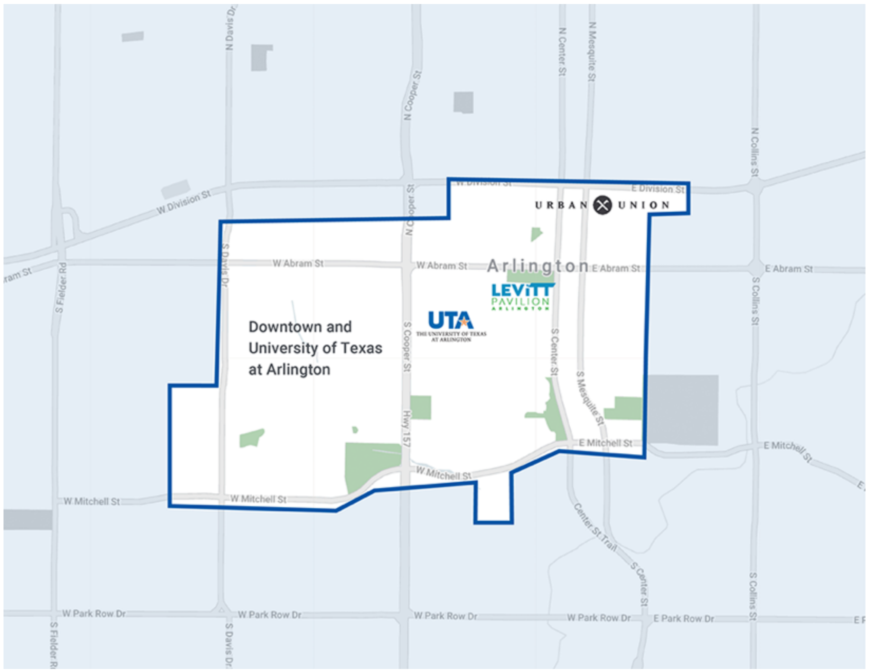

Figure 6-1 Service area of RAPID AVs

6.3.2 Data Collection

6.3.2.1 Self-Reported Survey

The research team developed an online survey questionnaire that was designed to enhance understanding of the attitudes, perceptions, and concerns of users and non-users of the SAV service who were 18 years or older and lived, worked, or studied in the city of Arlington. The questionnaire was reviewed by the Institutional Research Board (IRB) of UTA and distributed to a sample population for a pilot project. It was developed via an online platform, QuestionPro, and consisted of six parts: 1) SAV experience, 2) perception towards the SAV service, 3) attitude towards AV technology, 4) the participant's travel behavior, 5) residential accessibility, and 6) sociodemographic information. It was distributed with the help of City of Arlington and Via Transportation, and 717 people responded. After removing the responses with missing data, 264 valid responses remained.

6.3.2.2 Post-implementation Interviews

The research team also developed a semi-structured set of interview questions pertaining to individuals' travel behavior, perception of the SAV service, attitudes towards AV technology, and personal sociodemographic characteristics. A screening survey that would be used to identify potential participants was also developed. The protocol for both were approved by the UTA IRB. The screening survey was distributed through multiple channels, such as the university parking and transportation department, the City of Arlington's website, and Via's mobile application for all individuals who have used the RAPID SAV service at least once. The 31 individuals who showed interest in participating in the study by responding were sent a personal email, inviting them to the session, and providing them with a link that they could use to schedule the time that would be most convenient for them. The virtual interview sessions were conducted on the Microsoft Teams platform with the 11 people who responded: 4 UTA faculty or staff and 7 students. At the beginning of the interview sessions, the research team provided participants with abbreviated information about the study's goals and obtained their verbal consent to participate. The average length of the interviews was 29 minutes.

6.3.3 Data and Variables

6.3.3.1 Survey Data

- Willingness to Ride SAVs

One of the questions on the survey asked the participants to indicate to what extent they would be willing to utilize the service. Responses were on a 5-point Likert scale, where 1= strongly likely and 5 = strongly unlikely, as shown in Table 1.

- Attitudes towards AV technology

Eight statements in the questionnaire were designed to discern the individuals' attitudes toward AV technology by asking them to what extent they agree/disagree with a statement. Responses were indicated by rating their agreement/disagreement from 1 = strongly disagree to 5 = strongly agree, as shown in Table 2.

- Sociodemographic

The respondents were also asked about their sociodemographic characteristics, such as employment status, student status, whether they had a valid driver's license, and the number of vehicles in their household, as shown in Table 3.

6.3.3.2 Interview Questions

To identify the travel behavior of the users and non-users, the interview participants were asked about: 1) their current means of transportation and how frequently they use it; 2) their experience riding the RAPID SAV service (e.g., trip purpose, waiting time, trip cost, pick-up & drop-off location, sharing the ride with others, etc.); 3) the challenges and benefits of AV technology; and 4) personal sociodemographic characteristics (age, residential location, number of vehicles in their household, student/employment status, and education level).

6.4 Data Analysis and Results

6.4.1 Quantitative Analysis of Survey data

- *Dependent Variable*

A single dependent variable was used for this study, based on the following survey question: "If the RAPID service continues to provide rides in Arlington, how likely would you be to ride the service?" The participants were asked to provide their response on a 5-point Likert scale: 1= strongly unlikely, 2= unlikely, 3 = neither unlikely nor likely, 4 = likely, 5 = strongly likely. The results indicated that 64.8% of the respondents were strongly likely to utilize the service, as shown in Table 6-1.

Table 6-1 Willingness to Ride SAVs

If the RAPID service continues to provide rides in Arlington, how likely would you be to ride the service?		
	Frequency	Percent
Strongly unlikely	5	1.9
Unlikely	2	0.7
Neither unlikely nor likely	7	2.7
Likely	79	29.9
Strongly likely	171	64.8
Total	264	100.0

- *Independent Variables*

The study found that 8 of the 13 variables that have the potential to influence the willingness of individuals to ride SAVs (Table 6-2) are related to attitudes towards AV technology; the other five independent variables are related to personal characteristics, such as employment status (full-time or part-time), student status, valid driver's license, and number of vehicles in household, as shown in Table 6-3.

Table 6-2 Attitude towards AV Technology (n=264)

Variables	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1) AVs can increase the convenience of travel.	1.1	0.4	16.3	42.8	39.4
2) AVs can make my trips easier since I will no longer need to look for parking.	1.9	1.5	13.3	39.4	43.9
3) Cyber security is a concern.	1.5	12.1	31.5	28.0	26.9
4) Confusion among human drivers and AVs on the streets is probable.	2.3	10.2	31.8	35.6	20.1
5) AVs can make transportation safer.	1.9	2.3	35.6	34.8	25.4
6) I would recommend AVs to my family and friends.	1.9	1.5	35.6	34.9	26.1
7) I support AV technology.	1.1	1.1	20.1	41.7	36.0
8) I prefer riding an AV to driving myself.	6.1	11.0	39.0	22.3	21.6

A descriptive analysis of the participants' characteristics revealed that a majority (86.7%) of them were students. A few (12.9%) were employed full-time, and more than a quarter of them (38.6%) were employed part-time. More than half of the participants (67.0%) had a valid driver's license, and 73.1% of them had at least one vehicle in their household.

Table 6-3 Personal Characteristics of Respondents

Variable	Category	Frequency	Percentage
1) Employment: Full-time	Yes	34	12.9
	No	230	87.1
2) Employment: Part-time	Yes	102	38.6
	No	162	61.4
3) Student status	Yes	229	86.7
	No	35	13.3
4) Valid driver's license	Yes	177	67.0
	No	87	33.0
5) Vehicles in household	None	71	26.9
	One or more	193	73.1

6.4.2 Regression Analysis

An ordinal regression model was used to identify the variables that will significantly impact individuals' willingness to ride SAVs in the future. Linear regression was used to identify any multicollinearity between the independent variables by examining the tolerance and variance inflation factor (VIF) as shown in (Table 6-4). A small tolerance value indicates that the variable under consideration is almost a perfect linear combination of the independent variables already in the equation and that it should not be added to the regression equation. Results indicated the tolerance value of all the independent variables was greater than the cut-off value of 0.1 (Tabachnick & Fidell, 2001) suggesting a low correlation among variables. VIF measures the impact of collinearity of variables in a regression model and a high VIF value indicates multicollinearity among the variables. The VIF value of all the independent variables for our model was less than the cutoff value of 10 (Menard, 2002) indicating satisfactory results.

Table 6-4 Collinearity Statistics

	Tolerance	VIF
AVs can increase the convenience of travel.	0.559	1.788
AVs can make my trips easier since I will no longer need to look for parking.	0.535	1.868
Cyber security is a concern.	0.753	1.328
Confusion among human drivers and AVs on the streets is probable.	0.744	1.344
AVs can make transportation safer.	0.411	2.435
I would recommend AVs to my family and friends.	0.368	2.718
I support AV technology.	0.405	2.467
I prefer riding an AV to driving myself.	0.651	1.537
Employment: Full-time	0.741	1.349
Employment: Part-time	0.876	1.142
Student status	0.763	1.311
Valid driver's license	0.801	1.249
Number of vehicles in household	0.803	1.245

Next, we explored the relationship between the dependent and the independent variables by performing an ordinal logistic regression analysis. A total of 13 variables were used in the model, and the test of parallel lines was performed to check the assumption of proportional odds shown in Table 6-5. The results indicated that the model achieved a significance level of >0.05 (p=0.90), satisfying the proportional odds assumption. The model fit parameters showed significant results, with the Pearson Chi Square test (p=1.00) and deviance test (p=1.00) >0.05 indicating a good model fit.

Table 6-5 Test of Parallel Lines

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	340.843			
General	312.647[b]	28.196[c]	39	.900

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories[a].
a. Link function: Logit
b. The log-likelihood value cannot be further increased after maximum number of step-halving.
c. The Chi-Square statistic is computed based on the log-likelihood value of the last iteration of the general model. The validity of the test is uncertain.

6.4.3 Results of Regression Analysis

Table 6-6 provides estimates of the parameters of 13 independent variables and assesses their likely impact on the dependent variable established in the model. In this model the dependent variable is focused on measuring an individual's willingness to ride SAVs in the future. The standard interpretation of these estimates is that a one unit increase in the independent variable is expected to change the dependent variable level by its respective regression coefficient in the ordered log-odds scale, given that all variables in the models are held constant.

Table 6-6 Parameter Estimates

						95% Confidence Interval	
	Estimate	Std. Error	Wald	df	Sig.	Lower Bound	Upper Bound
[Willingness to ride SAVs = 1]	-0.310	1.200	0.067	1	0.796	-2.663	2.043
[Willingness to ride SAVs = 2]	0.255	1.175	0.047	1	0.829	-2.049	2.558
[Willingness to ride SAVs = 3]	1.248	1.161	1.155	1	0.282	-1.028	3.523
[Willingness to ride SAVs = 4]	4.271	1.195	12.776	1	<.001	1.929	6.613
AVs can increase the convenience of travel.	0.077	0.232	0.110	1	0.740	-0.378	0.531
AVs can make my trips easier since I will no longer need to look for parking.	0.461	0.217	4.507	1	0.034	0.035	0.886
Cyber security is a concern.	-0.147	0.162	0.827	1	0.363	-0.463	0.170
Confusion among human drivers and AVs on the streets is probable.	-0.396	0.191	4.294	1	0.038	-0.770	-0.021
AVs can make transportation safer.	-0.168	0.240	0.487	1	0.485	-0.639	0.303
I would recommend AVs to my family and friends.	0.425	0.251	2.853	1	0.091	-0.068	0.917
I support AV technology.	0.292	0.254	1.322	1	0.250	-0.206	0.789
I prefer riding an AV to driving myself	0.622	0.164	14.302	1	<.001	0.300	0.944
[Employment: Full-time = Yes]	-0.768	0.460	2.787	1	0.095	-1.670	0.134
[Employment: Full-time = No]	0[a]	.	.	0	.	.	.
[Employment: Part-time = Yes]	0.303	0.323	0.878	1	0.349	-0.330	0.936
[Employment: Part-time = No]	0[a]	.	.	0	.	.	.
[Student = Yes]	1.108	0.457	5.874	1	0.015	0.212	2.005
[Student = No]	0[a]	.	.	0	.	.	.
[Valid driver's license = Yes]	-0.770	0.372	4.284	1	0.038	-1.498	-0.041
[Valid driver's license = No]	0[a]	.	.	0	.	.	.
[Vehicle in household = None]	-0.015	0.387	0.001	1	0.969	-0.773	
[Vehicle in household = One or more]	0[a]	.	.	0	.	.	

Link function: Logit.
a. This parameter is set to zero because it is redundant.

The results in Table 6 indicate that the following seven independent variables have a significant relationship with the dependent variable: a) AVs can make my trips easier since I will no longer need to look for parking, b) confusion among human drivers and AVs on the streets is probable, c) I would recommend AVs to my family and friends, d) I prefer riding in an AV to driving myself, e) full-time employment, f) student status, and e) valid driver's license. On the other hand, the following did not have a statistically significant relationship with the dependent variable: a) AVs can increase the convenience of travel, b) cyber security is a concern, c) AVs can make transportation safer, d) I support AV technology, e) part-time employment, and f) at least one vehicle in the household.

The results indicated a statistically significant relationship between AVs making the trip easier and the dependent variable ($p=0.034$), indicating that individuals who believe that AVs will make trips easier because there is no need for parking the vehicle are 0.461 more likely to use them. There is a statistically significant negative relationship between AVs creating confusion on streets and the dependent variable ($p=0.038$), which means that individuals who do not trust AVs' performance on public roads are 0.396 times less like to use them in the future. When the attitudes towards recommending AVs to others were analyzed, the results indicated a statistically significant relationship with the dependent variable ($p=0.091$). This means that individuals who recommend AVs to their friends and families are 0.425 times more likely to use SAVs themselves. The results also revealed that the preference of riding in AVs rather than driving has a significant relationship with the dependent variable ($p<0.001$), suggesting that individuals who prefer to ride in AVs instead of driving themselves are 0.622 times more likely to ride in SAVs. When current employment status was analyzed, a significant relationship between full-time employment and the dependent variable ($p=0.095$) was revealed, suggesting that individuals who are employed full-time are 0.768 times less likely than those employed part-time to use SAVs. When student status was analyzed, the results indicated a significant relationship between students and the dependent variable (p=0.015), meaning that students are 1.108 times more likely to use SAVs. When the status of having a valid driver's license was analyzed, the results indicated a statistically significant relationship with (p=0.038), meaning that individuals who have a valid driver's license are 0.770 times less likely to ride in SAVs in the future.

6.5 Qualitative Analysis of Interview Participants

6.5.1 Descriptive Statistics of interview Participants

Among the 11 who were interviewed, 7 had used the RAPID SAV service at least once. Most of those who had utilized the SAV service were university students between the ages of 18 and 25, and 4 out of 7 of them used it to get from one place to another on campus. SAV users used Via to travel from place to place in Arlington and other app-based on-demand private services (Uber & Lyft) to travel outside Arlington because Via does not provide that service. SAV users usually take advantage of on-demand ridesharing services for grocery shopping multiple times per week because it was provided by UTA for free for students. Four of the 11 individuals had no experience riding RAPID. Three were employed full-time and used their personal vehicles to get to work, and the SAV non-users used their cars for grocery shopping and errands as shown in Table 6-7.

Table 6-7 Personal Characteristics of Interview Participants

#	Gender	Age	Home Zip Code	Valid Driver's License	Vehicles in Household	Student Status	Employment Status	Education Level	RAPID SAV User	Usual Mode of Transport		Travel Purpose
P1	Male	DNA	76010	Yes	1	Yes	Full-time	Undergraduate	Yes	Via	→	Grocery and Work
P2	Male	25	76010	No	0	Yes	Part-time	Graduate	Yes	Via UTA Transportation	→ →	Grocery School
P3	Female	DNA	76013	Yes	1	No	Full-time	Ph.D.	Yes	Via UTA Transportation	→ →	Grocery & Medical Shopping
P4	Female	22	76013	No	0	Yes	Part-time	Undergraduate	Yes	Via	→	Grocery
P5	Male	24	76013	Yes	0	Yes	Part-time	Graduate	Yes	Via Uber/Lyft	→ →	Grocery Recreational
P6	Female	21	76013	No	1	Yes	Unemployed	Undergraduate	Yes	Via Uber/Lyft	→ →	Grocery Recreational
P7	Male	18	76013	Yes	2	Yes	Part-time	Undergraduate	Yes	Via	→	Grocery & Recreational
P8	Female	DNA	75052	Yes	1	No	Full-time	Graduate	No	Personal Vehicle	→	Work
P9	Male	22	76010	Yes	1	Yes	Part-time	Undergraduate	No	Uber/Lyft	→	Grocery
P10	Female	57	75040	Yes	2	No	Full-time	Graduate	No	Personal Vehicle	→	Work & Grocery
P11	Female	DNA	76013	No	1	No	Full-time	Graduate	No	Via and Carpool	→	Work & Medical

Note: DNA (Did Not Answer)

6.5.2 Content Analysis

The virtual interview sessions were audio- and video-recorded and were transcribed using the Microsoft Teams platform. The qualitative data obtained from the interviews was systematically organized and analyzed using MAXQDA Analytics Pro software because it was used in earlier qualitative studies on Avs (Hilgarter & Granig, 2020; Joisten et al., 2021; Nordhoff et al., 2019; Pakusch et al., 2018) and provides a wide range of tools for complex coding, high data capacity, transcription, and visualization. The qualitative content analysis method was used to analyze the textual data collected through open-ended questions from individual interviews (Forman & Damschroder, 2007), and an open coding approach was adopted for reviewing the interview transcripts. The main themes were coded in terms of five main dimensions discussed by the participants in the interview sessions (travel behavior, perceptions, concerns, preferences, and attitudes); then the subthemes were coded based on the details provided by each participant in terms of service quality, AV challenges, AV benefits, willingness to pay, future AV acceptance, and reason for use. Each theme and sub-theme had multiple quotes; however, a limited number of quotes were used to maintain clarity.

6.5.3 Results of Content Analysis

6.5.3.1 Perception of Users about SAV Service Quality

- *Pick-up and Drop-off Locations*

Three SAV users were unsatisfied with the pick-up and drop-off locations of the RAPID AVs, and one participant mentioned that in contrast with other on-demand ride services, such as Uber and Lyft that allow the rider to select the pick-up location, the Via app automatically selects the pick-up point for RAPID rides. As a result, individuals must walk a little to reach their destination. One participant stated that he stopped using the RAPID service because he was once dropped off at a pre-programmed geographical location instead of where he intended to go, which required him to walk farther. Another participant stated that the SAV arrived at a different location than what was stated on the Via application.

- *Waiting Time*

The wait time for the four individuals who used the RAPID SAV service was less than 10 minutes; however, one SAV user stated that she experienced wait times varying from 3 to 25 minutes every time she booked an SAV ride. Another SAV user shared similar wait times of 4 to 28 minutes.

- *Sharing ride with others*

The SAV users were asked how frequently they share a ride with another passenger. Two responded that they are the only passenger most of the time, and the other said that he almost always shares the ride with someone else. Based on the responses, it can be concluded that regular users of the service usually share their rides with others, while those who have only used the service one or two times have not.

- *SAV App*

Three SAV users were satisfied with the user interface of the SAV application: the accuracy of the waiting time displayed on the app, the ability of the app to show the live location of the users while they are inside the vehicle, and the ease of identifying the service boundaries of Via and RAPID due to being marked with different colors.

- *Ride Comfort*

The participants reported that they were very satisfied with the seating arrangement and the cleaning practices adopted during the pandemic. One participant stated he was comfortable sitting

Table 6-8 Users' Perceptions About Quality of the Current SAV Service

Theme	Sub-Themes	Example quotes
Users' Perception	Pick-up and Drop-off Locations	*P1 - "I didn't like the fact that they'll be at a certain location and its preprogramed geographical location and not the location I wanted to be at. So, I ended up walking further down the street to be at the place I wanted to go."* *P5 - "Sometimes what happens is that it shows the four minutes that it's arriving in four minutes, and usually the pickup is at SWIFT center. So, we also think that the pickup would be SWIFT center, but sometimes it goes through Greek Row."* *P6 - "Well, for the most part like what happens with Uber or Lyft, as you said? You know a point where you have to be picked and you expect the ride to be there. But with Via your location changes a little bit."*
	Waiting Time	*P1 - "Three to five minutes. It didn't take that long."* *P3 - "Our wait time once we booked on Via was within 5 minutes."* *P4 - "It really kept changing. Sometimes would be like 20 minutes or so and sometimes it was three minutes or so. So, I'm going to say a range of 3 to 25 minutes."* *P5 - "It depends. Like uh, sometime it takes 3 minutes, 4 minutes, sometime it takes 28 minutes and more."* *P6 - "It as long as I remember it was 10 minutes."* *P7 - "I think it was about 10 minutes."*
	Sharing ride with others	*P1 - "I didn't really have anyone inside the car typically, depends on how busy it was."* *P2 - "Not until I have not shared my ride with anyone."* *P4 - "Actually, you know most of the time."* *P5 - "Nearly every time."* *P6 - "It was twice or thrice when the campus activities started."* *P7 - "No, I didn't. I think that it was just me."*
	SAV App	*P1 - "I was actually impressed with the RAPID ride because the wait time. they say on the app was the same time it showed up."* *P2 - "Yeah, because it's user friendly because I don't see any difficulty in selecting the RAPID services because it's the same thing."* *P3 - "I mean the app is easy to use as far as payment. I can see you know where it's going to pick me up. It's very clear where it's going to drop me off and I like how it shows you traveling in the app."*
	Ride Comfort	*P1 - "So, I like the fact that it was comfortable, it was clean, the seating, the padding and everything was good. It was roomy."* *P2 - "Because they had sanitized before I hop in and after I hop off. Yeah, I did feel that it's safe and all the precautions are being followed."* *P5 - "And if I'm sharing a ride with anyone else, I cannot put my stuff anywhere because like it's I have a limited confined space to put in my stuff."*
	Ride Safety	*P1 - "So, like I already said, I'll be neutral because of the fact that there's certain turns and certain curves that the car can't take but just going straight."* *P2 - "So, I feel pretty safe, and it was like a normal thing. Like it was little like the way I ride in either Via or Uber or Lyft, where a normal human being is the one who's controlling the vehicle."* *P3 - "I felt safe when I knew it was going to stop or slow down by the intersections."* *P4 - "But the fact that there's a person, a driver who's kind of controlling. Uh, give me more reassurance and so that made it more even more comfortable"* *P5 - "Like I'm very open to try out new things. It's just a concern of safety that could just bother me. What if the system fails? What if it crashes so I don't know anything right now about those safety systems."* *P6 - "I realize there are some safety issues where the car would sometimes not stop and the driver has to do it by himself or, you know, taking like steep turns, where the driver has to come back to the steering wheel and make those turns by themselves."*

in the vehicle as it was sanitized every time he entered and left the vehicle. One participant, however, expressed concern about the limited storage space inside the vehicle, which makes it difficult to stow groceries or other items.

- *Ride Safety*

The ability of an autonomous vehicle to make tight turns in intersections was one of the major concerns of the participants. One mentioned that while riding the RAPID SAV, they learned that because the vehicle was unable to make tight turns, the driver would have to take the control of the vehicle. One participant stated that he was skeptical about the performance of the AV technology before riding in the AVs; however, he felt more confident after experiencing the technology firsthand and understanding how it works. One person stated that he was unaware of the safety systems provided inside the vehicle, so he was concerned about the crash mitigation system. Another participant felt reassured and comforted by seeing an onboard human attendant.

6.5.3.2 Attitude Towards AV Technology

- *AV Challenges*

Through discussion analysis, "lack of trust in technology" was revealed as one of the challenges of AV technology adoption. One SAV user stated that autonomous vehicles will be on the road sometime in the future, but it will take a long time for people to understand and trust the technology. Another SAV user suggested that a "lack of communication" between passengers and autonomous vehicles might present its own set of challenges.

The participants reported "technology reliability" as a major challenge for AV technology. For example, one rider was concerned about the accuracy of the wait time estimated by the app when booking a ride, and another expressed concern about the slow speed of the autonomous vehicle compared to regular traffic. A non-user stated that one main challenge of "technology reliability" would be reaching pick-up and drop-off locations at the stated time.

Technology safety negatively affects how people feel about using AVs. A non-user stated that the technology is not fully developed yet and has some uncertainties, which might have very bad consequences in terms of safety. One non-user expressed his concerns about the quirky behavior of autonomous vehicles stopping so far from an intersection, and two female non-users were concerned about using autonomous vehicles on main thoroughfares. One non-user mentioned that she would not feel safe riding autonomous vehicles outside the university campus area, and another non-user stated that she was comfortable riding in AVs on campus because she had seen them operating in that area.

- *AV Benefits*

Multitasking was reported as one of the major benefits of AV technology. One SAV user stated that autonomous vehicles allow individuals to perform multiple tasks like talking on the phone, checking messages, and working while traveling to their destination.

Transportation affordability is another advantage of autonomous vehicles. One non-user stated that people who cannot afford cars and need to use public transportation would greatly benefit from the implementation of shared autonomous vehicles. Another SAV non-user stated that the implementation of autonomous vehicles would improve transportation accessibility for underserved populations, like people with disabilities.

Cost efficiency was a major benefit of SAVs, according to the users. One stated that using shared autonomous vehicles benefits her financially and socially, since she can ride with her friends. Another user stated that SAVs are cost efficient.

Table 6-9 Attitudes towards Future SAVs

Themes	Sub-Themes	Example quotes
AV Challenges	Lack of Trust in Technology	*P2 - "I do believe that it will be taking a little longer for the people to believe that it will be really helpful for them, so I think it might take longer, but it will be little easier."*
	Lack of Communication	*P3 - "The smooth integration with picking up and dropping off multiple people when there's an actual driver that's been good communication with the driver, running late, coming early. Where are you now? I'm at the pick-up spot, you know you can call the driver. Say I'm close by, automated vehicle I'm not sure how that would work. It is a machine. If it was fully autonomous, they wouldn't have that personal connection there."*
	Technology Reliability	*P4 - "I'll just say the waiting time should be fixed and not the way they say. Oh your ride is taking longer. Sorry your ride is delayed, because if I'm in a rush I don't want to hear that"*
		P6 - "The vehicle when it's like on the run it's very slow compared to you know when a human drives"
		P8 - "I think the main thing would be like the reliability with timing, so like knowing that it would show up in a certain timeframe mean if it was like between these 10 minute slots or something that would be affected."
	Technology Safety	*P9 - "I feel like the technology probably definitely isn't there yet to actually begin rolling out completely. So now like a fully like autonomous vehicle, it needs to be like perfected because, you know, there's a lot of like potential like bad consequences, like for safety."*
		P9 - "I also feel them kind of do some weird stuff like they would stop like really far back form the intersection for no reason or maybe just above the stop sign and then stop. So just quirks that you feel like that, and also like the news that I hear, makes me like a wary of kind of going near one of them."
		P10 - "On public no. If it were just on the university around the campus, I I'd feel safe. I don't know that I would get on it to go outside of the university grounds."
		P11 - "You know, if it's around campus, I don't really have that many concerns. I have seen them around campus."
AV Benefits	Multitasking	*P2 - "As far as I see, it will benefit in terms of efficient working, and there will be no need for anyone to monitor the vehicle, and it will be a little easier."*
	Cost Efficiency	*P4 - "So yeah, it helps economically, and I would also say socially it's good because I know I can get a ride with my friends. Uh, like we can all fit for sure, so that's good"*
		P7 – "It's more cost efficient."
	Transportation Affordability	*P10 - "For one, maybe people that are disabled that would be very helpful for them."*
		P11 - "The ability for people to get around who may not have a vehicle is there another great advantage. You know, it's more cost efficient, probably less accidents on the road."
	Crash Mitigation	*P5 - "Also like there are many benefits that I could list. Some of them like they could avoid crashes."*
	Environmentally Friendly	*P3 - "Rideshare always helps the environment because of less carbon footprint and sharing."*
		P9 - "Environmental probably that. More people may be encouraged to carpool in them if they're both going to like the same destination."

Crash mitigation was stated as one of the benefits of AV technology. One user mentioned that AV technology will reduce car crashes because of less human intervention. Two participants also highlighted the environmental benefits of using shared AVs. One SAV user reported that SAVs help reduce the carbon footprint; a non-user stated that autonomous vehicles would reduce the carbon footprint by reducing the number of cars on roads and providing the opportunity for individuals going to the same destination to carpool.

6.5.3.3 Future Acceptance of AVs

A variety of responses were given when the respondents were asked to discuss the factors that would affect their acceptance of SAVs, but cost efficiency, travel distance, dedicated lanes, and the presence of a human attendant on board were those most often provided. One of the participants said that he would use AVs for short distances but would prefer traditional transportation for longer trips, and two others said that they would be more comfortable using AVs if they had dedicated lanes. The presence of an on-board human attendant was of primary importance to two participants, who said that they would only ride in AVs if a human attendant was on board.

Experience was also identified as an important factor affecting the adoption of SAVs. One user stated that he was concerned about the ability of AVs to navigate in heavy traffic, so he would have to use the service several times to build up his confidence. Trip purpose was another factor, and it was clear that shopping for groceries, drugstore items, etc. were the main reasons that most people would use SAVs in the future. Three non-users stated that they would use AVs for doing daily errands or grocery shopping if they were available in the future, and some said that they would use them for going to work and for recreational purposes.

6.5.3.4 Willingness to Pay

When asked about their willingness to pay for SAVs, most wanted free or discounted rates. They were willing to spend very little for using the service and expressed the desire for free or very low rates. One SAV user said that she would be willing to pay for using the autonomous vehicle service if it was cheaper than her existing mode of transportation. One SAV non-user stated that she would prefer to have a subscription-based model for paying for the AV service.

Table 6-10 Concerns and Preferences Towards Future SAVs

Themes	Sub-Themes	Example quotes
Future Acceptance of AVs	Cost Efficiency	*P1 - "So, I will use it, if it saves myself gas money."*
	Travel Distance	*P2 - "Yeah, if I had to travel or commute into smaller distances, I'll be using autonomous vehicles, but if I have to travel far from where I live or where I wanted to go with friends, I would prefer normal transport."*
	Dedicated Lanes	*P3 - "I think so, especially if it has its own lane. It's not weaving through traffic." s*
	On-Board Human Attendant	*P4 - "Yes, I would accept them, but keeping the fact that there's always going to be a driver controlling it and not just any driver, a licensed driver"*
		P7 - "I really like how RAPID is doing with having a supervisor or like having an attendant in the car to supervise all the actions made by the machine. And I feel like that's a good way to learn."
	Experience	*P5 - "Like I'll have some rides on that after having some rides I could figure out whether I should take that or not."*
	Purpose of Use	*P1 - "Walmart, Target you know different shopping centers we can look at and then there's other shopping places nearby."*
		P8 - "And it would have just been useful like to go to the grocery store or even to meet someone for lunch."
		P10 - "Like would it be for just going down the street to get groceries? Yeah, I would definitely do that."
		P7 - "If I was given the autonomous vehicle, I would use it to errands then at that point it would replace my gasoline vehicle for that."
		P9 - "I would do anything for all general purposes. You know, going to work, doing routine errands, just driving around, like traveling, maybe."
Willingness to Pay	Free or discounted rates	*P1 - "I will still ride it if it was free and infinite. Like if there is a little bit of a charge. Then I'll be OK with that. Because you know, everything is not free."*
		P6 - "Of course I would still use the autonomous vehicle with the points. As I said, if the safety gets better, if the price does not go up compared to the normal Via if it stays $3, something more affordable."
		P8 - "I would definitely be willing to pay like a monthly service fee."

6.6 Discussion

This study investigated individuals' attitudes toward AV technology through an ordinal logistic regression model that used survey data collected from users and non-users of a pilot SAV service. Their perceptions and attitudes were analyzed by using qualitative data derived from personal interviews with 11 individuals who provided valuable insights about their views of the quality of existing SAV services, what they considered the biggest challenges and benefits of future SAVs, their primary preferences and concerns about the service, and how much they were willing to pay for it.

Jing et al. (2019) espoused that convenience impacts the use of shared autonomous vehicles, and the results from our ordinal logistic regression model agree that the convenience of SAVs is significantly associated with a willingness to use the service. Individuals who felt that SAVs are more convenient due to not needing to park the autonomous vehicle were shown to be more likely to adopt SAVs in the future. This finding is in line with (Lee et al., 2018), who suggested that acceptance of fully autonomous vehicles is significantly impacted by user convenience. Multitasking was also shown to be an important factor, as users indicated that they would enjoy working enroute, since they would not need to monitor the vehicle. These results revealed that many people would accept SAVs in the future if they perceived that the technology was more convenient and would improve their travel experience (Malokin et al., 2021).

The rate and efficacy of AV technology adoption depends to a great extent on how people perceive its safety (Shi et al., 2021). Regression analysis indicates that safety concerns about the ability of AVs to interact with other vehicles on the road can negatively impact individuals' willingness to use them. Autonomous vehicles will be sharing the roads with traditional vehicles in urban areas, making it difficult for other road users like pedestrians and bicycle users to identify the vehicles and interact with them safely (J. Wang et al., 2020). Likewise, the findings of the content analysis support the regression results and indicate that safety is an important element that affects the perception of users towards quality of the service, the attitudes of actual and potential users towards SAV challenges, and future acceptance of SAVs. Users must have a higher degree of trust to accept the AV technology (Adnan et al., 2018). The interviews with SAV users revealed that “ride safety” was important to them, as they expressed concern about their inability to make tight turns in intersections. Future AV services must demonstrate their capacity to appropriately maneuver at intersections to gain riders' trust and create a safe and secure environment. Interview results suggested that technology safety is one of the most crucial SAV challenges. SAV non-users were cautious about using autonomous vehicles outside the university campus; SAV users were also skeptical about riding AVs, but they became more confident after experiencing the technology firsthand and understanding how it works. This is in-line with the findings of Salonen & Haavisto (2019), which indicated that riding in AVs can significantly improve the perception of individuals about their safety. Providing the chance to test AV technology in a real-world, safe, and secure setting improves people's attitudes about autonomous vehicles (Salonen & Haavisto, 2019). Transit agencies that are planning to integrate autonomous vehicles with existing transportation infrastructure should consider initiating pilot projects, deploying AVs in a limited area to make the public familiar with the AV technology. In addition, exploring the concerns and preferences for future acceptance of SAVs through interview participants revealed that SAV users prefer to have a human attendant on board. This is consistent with findings that people prefer having a human operator on board an autonomous vehicle versus fully automated driving Nordhoff et al. (2019). Consequently, future AV services should consider having a human attendant on board that can monitor the technology and surroundings to promote trust and improve the perception of AV technology.

Understanding how the general public feels about AVs is important because it will determine how successfully they are integrated into existing traffic systems (Penmetsa et al., 2019; Rahman et al., 2021). We explored the perceptions of frequent and non-frequent users and found that frequent SAV users experience long waiting times compared to infrequent users. In addition, because RAPID SAV offers real-time ridesharing, drivers may accept the request of other riders during a trip, thereby increasing the wait time for other riders. One possible solution may be increasing the fleet size of the rideshare services, based on the demand, to minimize the passengers' waiting times and promote a positive perception of ridesharing adoption and use (Hörl et al., 2019; Vosooghi et al., 2019).

In the future, with greater market penetration, AVs may offer a variety of advantages, such as the ability to save money (Woldeamanuel & Nguyen, 2018). The content analysis of this study showed that cost efficiency is an important benefit of SAVs, and RAPID users believe that AVs are cost efficient, as they allow people with the same destination to rideshare. Environmental friendliness was also shown to be an important part of individuals' attitudes towards SAV benefits. Both SAV users and non-users felt that the use of SAVs would help reduce the carbon footprint by allowing ridesharing. Similar findings were reported by (Woldeamanuel & Nguyen, 2018), who discovered that the most important advantage of autonomous cars to both millennials and non-millennials is the reduction in greenhouse gas emissions.

The existing literature emphasizes the importance of attitudinal variables in willingness to use AVs (Asgari & Jin, 2019; Morita & Managi, 2020; Rahimi, Azimi, Asgari, et al., 2020). The regression results of this study, indicating that students are more likely to ride SAVs in the future, were expected, since the RAPID service area was limited to downtown Arlington and the UTA campus and might not have provided access to others' desired destinations. The interview results support the regression results, indicating that SAV users are individuals using existing app-based on-demand services in the area because they do not have access to private transportation. This result supports the findings of (Rahimi, Azimi, Asgari, et al., 2020), who discovered that while public transportation users or passengers are less willing to pay for autonomous vehicles, they are more interested in their adoption than private vehicle users. In addition, regression results indicated that individuals having a valid driver's license are less likely to ride in SAVs, implying that experienced drivers are less willing to use autonomous vehicles. These results complement those of (Tan et al., 2019), who espoused that people with a negative attitude toward AVs are more likely to obtain a driver's license in the future. Content analysis also revealed that both SAV users and non-users would prefer to use them for shopping trips; therefore, providing services to major shopping destinations, including grocery stores, would increase the ridership of SAV services. Increasing the service area throughout the city of Arlington might also increase ridership, as individuals could gain access to a greater variety of destinations (Etminani-Ghasrodashti et al., 2021b). Despite the convenience, however, the interview participants indicated that both RAPID users and non-users were not willing to pay much for the use of the AV service.

6.7 Conclusion

The pace at which new technology is adopted or implemented is largely determined by the general public's perception and acceptance of it. Individual expectations, experiences, and attitudes toward AV technology will impact future SAV adoption and policies that govern transportation systems. Therefore, evaluating existing travel behavior, issues, concerns, and preferences related to AV pilot projects is crucial for its successful deployment in rural and urban locations.

The results of this study imply that experiencing AV technology can significantly increase individuals' willingness to ride in SAVs. Two of the major reasons that people do not avail themselves of the service are lack of awareness and lack of accessibility. Marketing and awareness campaigns that highlight the advantages of using the AV technology can increase the number of users, and the continued implementation of SAV pilot demonstrations can be beneficial by making individuals more aware and familiar with the technology. Pilot demonstrations can also help researchers and policymakers understand the factors that determine whether potential riders trust the technology. In essence, SAV service providers need to disseminate the benefits of SAV technology and provide a lower cost service for the underserved and transit dependent population.

The limitations of this study include the sample size, the homogeneity of the sample populations, and the lack of data on paying customers, as follows:

Sample size: The sample size of the interview participants was quite limited because the study was conducted during the implementation stage. Moreover, since the interview sessions were conducted virtually, technologically disadvantaged individuals were unable to participate.

Homogeneity of the sample populations: The majority of the participants in the study were affiliated with UTA because the RAPID service operations were limited to areas surrounding the campus.

Lack of data on paying customers: This study focused on an SAV service that was provided free to UTA students. A similar study that focuses on the general public who pays for the service is needed to identify the factors affecting their future SAV adoption.

CHAPTER 7

EXPLORING PEOPLE’S ATTITUDE AND PERCEPTIONS OF USING SHARED AUTONOMOUS VEHICLES: A FOCUS GROUP STUDY

7.1 Abstract

Shared Autonomous vehicles are one of the most anticipated advancements in the smart mobility domain, with the potential to revolutionize transportation. Individual attitudes and adoption of shared autonomous vehicles (SAVs) have been studied in the literature, focusing on potential users and non-users of SAVs with little or no experience using the technology. We focus on an SAV pilot project called RAPID (Rideshare Automation and Payment Integration Demonstration) in Arlington, Texas, and provide a realistic view of people's responses to self-driving vehicles. This study intends to identify individual attitudes, perceptions, and concerns concerning the RAPID SAV service following its integration into existing on-demand ridesharing service. We used a two-step approach for this study. First, this study analyzes the survey data collected from the users of the SAV service. Results indicated that seating comfort and boarding were highly rated by SAV users. Moreover, waiting time and pick-up and drop-off location were the lowest rated attributes by the SAV users. Second, we conducted a focus group of 4 individuals with users and non-users of the service to gain in-depth insights in the post-deployment phase of the project. Our findings indicate that service availability, geographic accessibility, and higher service cost were the three major concerns of the participants. Lack of accessibility and lack of awareness were two major reasons for not riding the service. This study provides insights into the perception and attitude of SAV users and non-users that will help transit agencies successfully implement future SAV services and develop and design policies accordingly.

7.2 Introduction

Autonomous vehicles (AVs) are expected to bring a paradigm shift in future transportation mobility along with other innovative technologies like electric vehicles, micro-transit, and on-demand mobility services (Hilgarter & Granig, 2020). AVs will alter the transportation industry in terms of user experience, transportation modes, and business models (Chan, 2017). The emergency of autonomous vehicles will disrupt the travel patterns, vehicle ownership, residential pattern and vehicle miles/kilometers traveled (Zmud & Sener, 2017). The predominant mode of travel in the United States is the personal vehicle or light truck with at least 24% of households having three or more vehicles (Center for Sustainable Systems, 2021). This increase in the number of private vehicles causes traffic congestion, greenhouse gas emissions, and fatal accidents (Hilgarter & Granig, 2020). The United States reported 5.3 million crashes in 2011, resulting in 2.3 million minor injuries and 32000 fatalities (Anderson et al., 2016). AVs are expected to provide multiple benefits by reducing traffic, improving fuel efficiency, decreasing emissions, preventing fatal crashes, and boosting mobility for people with disabilities (Fagnant & Kockelman, 2015). According to (Litman, 2020) analysis of the market penetration of autonomous cars, half of all new vehicle sales by 2045 and half of the fleet by 2060 will be accounted for by AVs. The National Highway Traffic Safety Administration has classified AVs into six classification levels: level 0 (momentary drivers assistance) to level 5 (full automation) (National Highway Traffic Safety Administration, 2022). In recent years, 17 SAV pilot projects have been implemented across the United States with operations on public highways or planned neighborhoods (Stocker & Shaheen, 2019). However, self-driving vehicles are not currently on roads except for a few AV testing and pilot projects, it is difficult to forecast the effects of autonomous vehicles with any certainty (Zmud & Sener, 2017).

Past studies have focused on the factors affecting the adoption of autonomous vehicles with most focused on sociodemographic variables like gender, age, income, and education (Haboucha et al., 2017; Hulse et al., 2018; Krueger et al., 2016; Lavieri et al., 2017; Schoettle & Sivak, 2015; Shabanpour et al., 2018; Wang & Akar, 2019; Wang & Zhao, 2019; Zoellick et al., 2019). Age was found to be a key determinant in the adoption of SAVs in most research, indicating that young people are more receptive to AV technology (Haboucha et al., 2017; Krueger et al., 2016; Lavieri et al., 2017; Zoellick et al., 2019). According to certain studies Wang and Akar (2019) and Wang and Zhao (2019), women are more concerned about the autonomous vehicle's safety and security and are less likely to use the technology.

Researchers have also emphasized the impacts of attitude on the adoption of autonomous vehicles (Asgari & Jin, 2019; Bansal et al., 2016; P. Liu, R. Yang, et al., 2019; Zhang, 2019). Asgari and Jin (2019) looked at the factors that influence people's willingness to pay for autonomous vehicles and found people are ready to pay for them if they save them money and time. The importance of service attributes in the adoption of AVs has been highlighted in some research indicating service cost, travel and waiting time, safety, and mobility as important indicators affecting the acceptance of SAVs (Jing et al., 2020; Krueger et al., 2016). Most of the recent studies have also used the quantitative approach to study the acceptance of autonomous vehicles using stated preference surveys (Gurumurthy & Kockelman, 2020; Kyriakidis et al., 2015; Penmetsa et al., 2019; Schoettle & Sivak, 2015; Wu et al., 2020). However, a majority of these studies discussed earlier focused on individuals with no AV ridership experience.

To the best of our knowledge, only four studies have looked at people's attitudes and perspectives after having first-hand experience with AV technology (Hilgarter & Granig, 2020; Nordhoff et al., 2019; Salonen & Haavisto, 2019). Hilgarter & Granig (2020) evaluated the perception of rural and urban inhabitants who experienced riding a Level 3 autonomous shuttle and discovered that the SAV users saw them as an alternative means of transportation rather than a replacement for current modes of transportation. Nordhoff et al. (2019) concluded similar findings, indicating that SAV users were inclined to employ autonomous shuttles as a feeder service for public transportation. According to Salonen and Haavisto (2019), people feel safe when riding the autonomous shuttle bus but are less tolerant of AV-induced mishaps than those caused by human drivers.

Although past studies provide information on individual preferences, and concerns about AV technology and identify the significant determinants impacting SAV adoption, some research questions are still unanswered. The literature lacks empirical assessments of riders' perceptions of SAV service attributes and features and their attitude towards AV technology development that will affect SAV adoption in the future because it mostly focuses on potential riders without actual ridership experience. This study provides insights into users and potential users perceptions and attitudes using data obtained from a ridership experience survey and focus group of 4 individuals providing a realistic view of people's perceptions and attitudes towards self-driving vehicles.

7.3 Research Methodology

7.3.1 Case Study

Arlington RAPID (Rideshare, Automation, and Payment Integration Demonstration) is a pilot project in the City of Arlington, Texas that operated from March 2021 through March 2022. It was a collaboration between the City of Arlington, Via Transportation, May Mobility, and the University of Texas at Arlington (UTA) that integrated an AV transportation service with an existing on-demand ridesharing service. Under this project, autonomous vehicles provided service to downtown Arlington and on the university campus, giving free rides to students from 7:00 AM to 7:00 PM Monday through Friday (City of Arlington, 2021b). The service was comprised of four Lexus hybrid cars and one Polaris GEM vehicle that was built to carry wheelchair users at speeds up to 25 mph. In Figure 7-1 below, the service area of the RAPID project is outlined in blue.

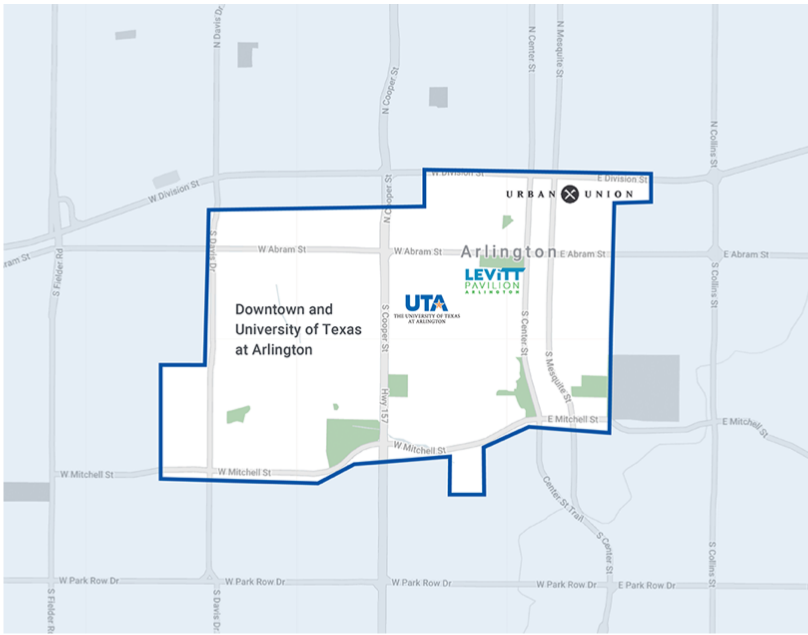

Figure 7-1 Service area of RAPID AVs

7.3.2 Data Collection

7.3.2.1 Ridership Experience Survey

The research team created a ridership experience survey to collect information from the users to rate their experience riding the RAPID SAVs. The target population for this study was anyone over the age of 18 who has utilized the RAPID service at least once. The IRB at UTA reviewed and approved the survey. The survey consisted of multiple sections with 16 questions related to RAPID service attributes and sociodemographic information. The survey was developed using QuestionPro an online survey platform, and distributed with the help of Via transportation through their app. About 402 people filled out the survey, and 261 (65%) completed responses were collected. The average time taken to complete the survey was approximately 2 minutes.

7.3.2.2 Focus Group

The research team developed a semi-structured set of questions about the perception of the SAV service, attitude towards SAV technology, and SAV adoption. We also developed a screening survey to identify the potential focus group participants. Both of these were reviewed and approved by the IRB at UTA. The screening survey was distributed through multiple channels like emails, the UTA electronic newsletter (MavWire), and the City of Arlington's website for all the individuals who have used the RAPID service at least once and those who have not used the service. A total of 16 individuals showed their interest in participating in the study by taking the screening survey. Next, an invitation email briefly explaining the study with the selected date and time of the meeting was sent to all the potential focus group participants. After multiple reminder emails, a total of 4 individuals accepted the invitation to participate in the study. The focus group session was conducted virtually on the Microsoft Teams platform with these individuals: 1 user and 3 non-users of the RAPID SAV service. At the beginning of the session, the moderator provided participants with brief information about the study goals and objectives and obtained their verbal consent to participate in the study. The focus group meeting lasted for approximately an hour.

7.2 Data Analysis and Results

7.4.1 Quantitative Analysis of Survey Data

7.4.1.1 Descriptive Statistics of Survey Participants

The descriptive analysis of ridership survey participants indicated that 66.3% of them were females and 28% were males. A majority (90.4%) of the participants were under the age of 35 years. More than half (56.7%) of the participants were Asian followed by African American (20.3%) and white

(12.3%) respectively. Almost 70% of these riders were from a low-income households of less than $35,000. Almost one-third (32.2%) of the survey participants had used the RAPID service just once, while 42.2% of participants used RAPID at least once a week as shown in Figure 7-2.

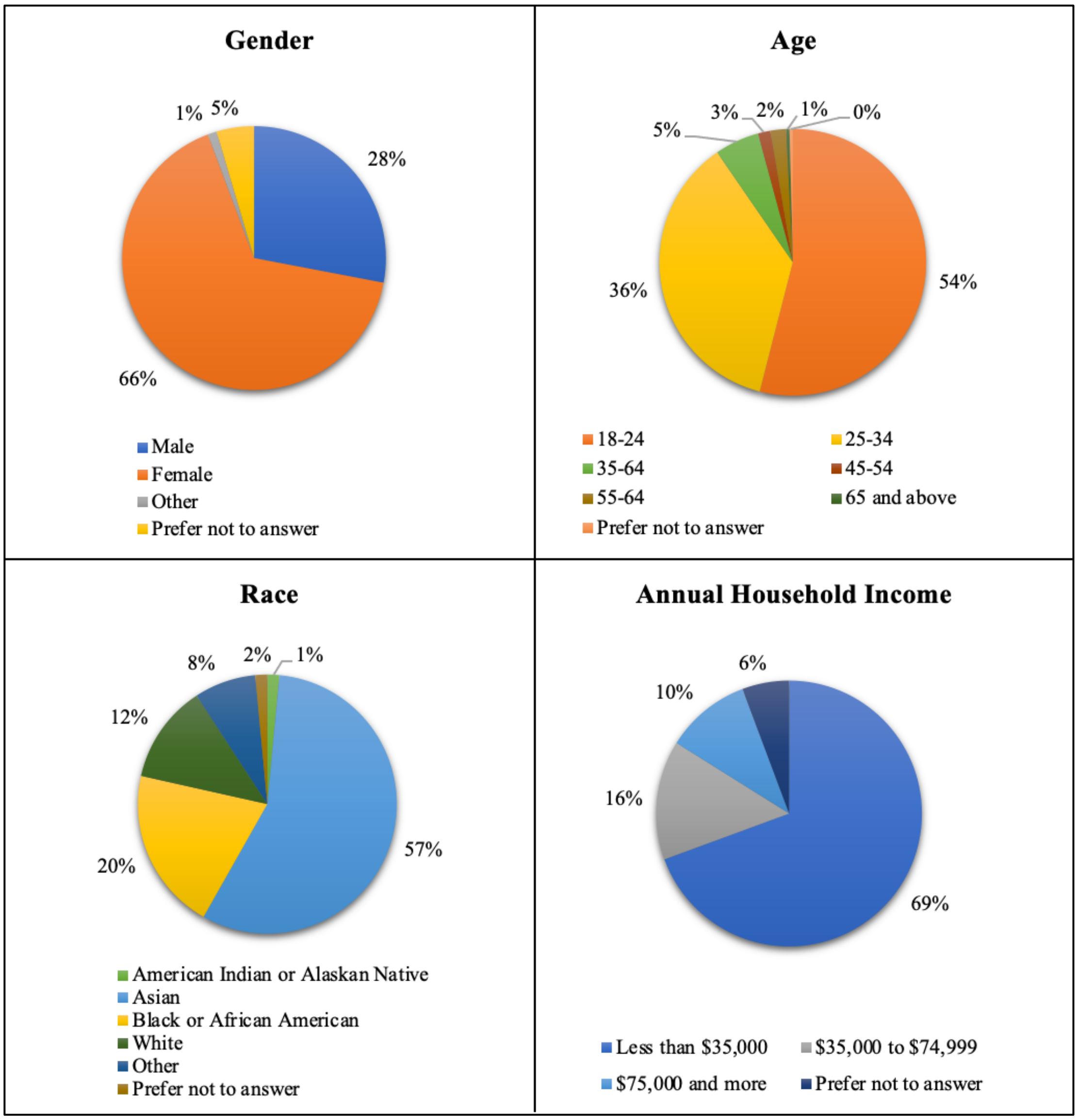

Figure 7-2 Descriptive Statistics of Survey Participants

7.4.1.2 Survey Results

The RAPID users were asked to rate their perception of RAPID service attributes based on response choices of not applicable for this ride, strongly disagree, disagree, neutral, agree, and strongly agree. A majority of the respondents showed a higher level of satisfaction with their experience riding the RAPID SAV service as shown in Figure 7-3.

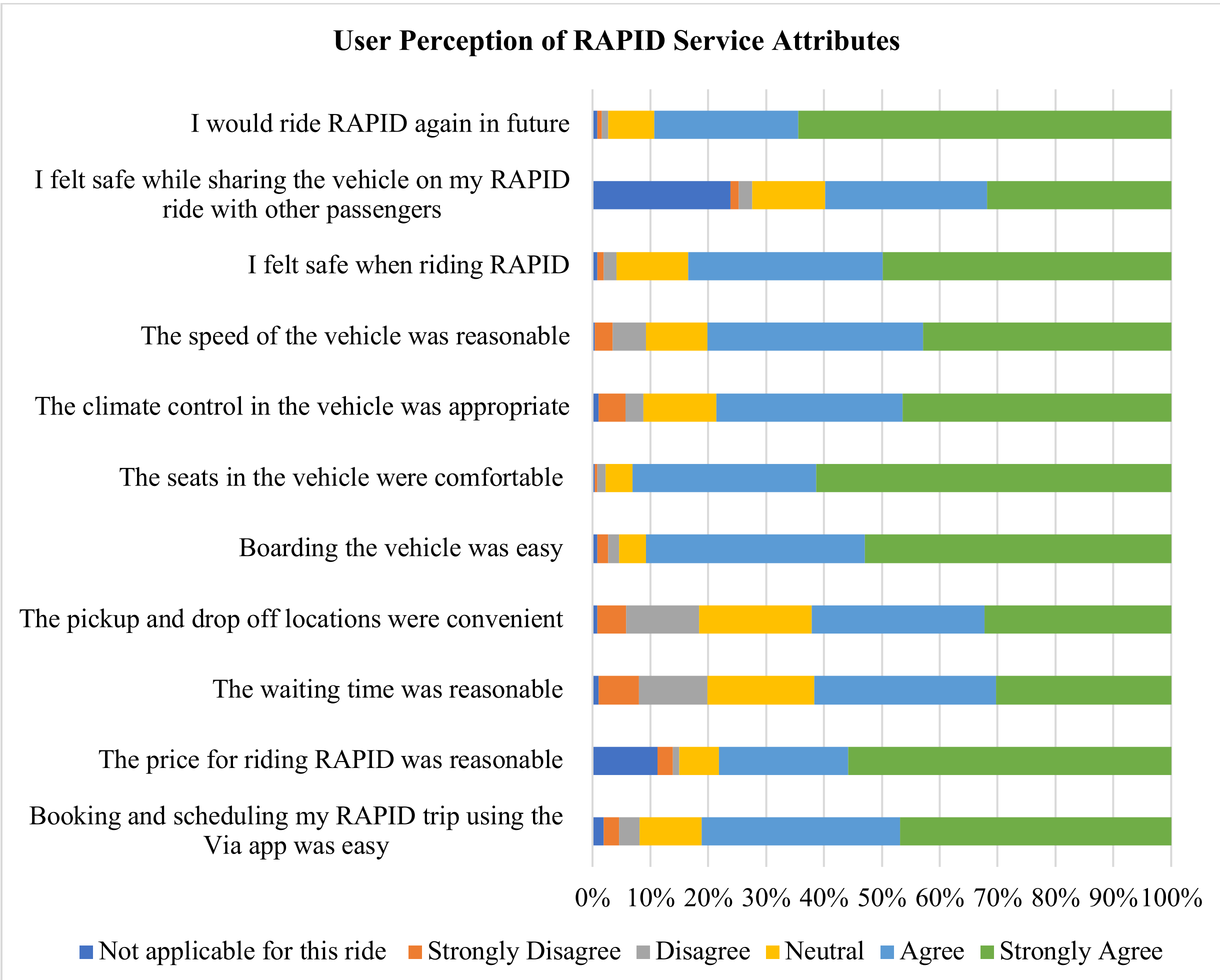

Figure 7-3 User Perception of RAPID Service Attributes (n=294)

Results indicated that respondents highly rated (agree or strongly agree) the seating comfort (93%), boarding vehicle (91%), and ride safety (83%). booking and scheduling (81%), vehicle speed (80%), climate control (79%), and service cost (78%) among the RAPID service attributes. Moreover, respondents rated waiting time (62%) and appropriate pick-up and drop-off location (62%) as the lowest rated attributes of the RAPID service. One possible explanation for these low ratings might be the high demand experienced during certain hours of the day and the nature of shared rides with aggregated pickup and drop-off locations. Only 60% of riders agreed they felt safe while sharing the ride with other passengers, but it is worth noting that 24% of respondents did not share their ride with any other passengers. Interestingly, 89% of the respondents agreed to ride the RAPID service again in the future as shown in Figure 3.

7.4.2 Qualitative Analysis of Focus Group Participants

7.4.2.1 Descriptive Statistics of Focus Group Participants

A total of 4 individuals participated in the focus group meeting. Three out of four individuals were females. Two participants were Asian, while the other two were white. A majority of these individuals were highly educated. All these individuals had a valid driver's license and at least one vehicle in their household for transportation. A majority (75%) of these participants were living off-campus.

Table 7-1 Personal Characteristics of Interview Participants

#	Gender	Age	Residential Location	Valid Driver's License	Vehicles in Household	Household Income	Education Level
1	Male	24	On-Campus	Yes	1	Less than $20,000	Graduate
2	Female	57	Off-Campus	Yes	1	DNA	Graduate
3	Female	26	Off-Campus	Yes	2	$50,000-$74,999	Graduate
4	Female	51	Off-Campus	Yes	1	$35,000-$49,999	Undergraduate

Note: DNA (Did Not Answer)

7.4.2.2 Content Analysis

The focus group session was both audio and video recorded and transcribed with the help of the Microsoft teams platform. The focus group transcript was managed and analyzed using the qualitative analysis software MAXQDA. We used the conventional content analysis method to analyze the textual data collected through open-ended questions in the focus group meeting (Forman & Damschroder, 2007), and an open coding approach was adopted for reviewing the interview transcripts. The main themes were coded in terms of two main dimensions discussed by the participants in the interview sessions in terms of perception of service attributes, concerns about existing SAV services, attitudes towards SAV technology, and preferences towards future SAVs. Each theme and sub-theme had multiple quotes; however, a limited number of quotes were used to maintain clarity.

7.4.2.3 Results of Content Analysis

- *Service Attributes*

When asked about waiting time for RAPID SAVs, an SAV user mentioned he would book a ride 20 – 30 minutes in advance because the ride might get late occasionally. Participants were not satisfied with the pick-up and drop-off locations of the RAPID AVs. An SAV user mentioned that the RAPID SAV does not go inside his apartment and pick up or drop him off at the street even though the apartments have a lot of space for vehicles and parking. As a result, he has to walk about 2-3 minutes to reach his destination.

We asked participants about the experience while booking a RAPID ride on the Via app. One SAV user mentioned that the Via application used to book the RAPID SAV rides lags in providing accurate information to the customers about their rides. A non-user participant stated that using the Via application was easy as the user interface was relatively similar to other app-based on-demand services. When asked about ride comfort, an SAV user reported that he was satisfied with the seating arrangement and climate control of the autonomous vehicle.

Table 7-2 Perceptions About Quality of the RAPID SAV Service

Theme	Sub-Themes	Example quotes
Service Attributes	Waiting Time	- I will book around 20 minutes or 30 minutes before that because sometimes the ride might get late.
	Pick-Up & Drop-Off Location	- Earlier I said that sometimes it's showing the preferred pick-up location far away. But when I put my apartment as the drop-off location. The driver told me that we are not going inside the apartments, but my apartments are very big in size. And if you know the west campus I stay in Meadow Run apartments. So there is a lot of space for the vehicles to enter and also for the parking. But she told me that we have to drop you here because it's the location. So I'm not sure why they told me like that. I think every time they will say that we can't go inside your apartments. So we have to drop you here or outside of the street. From there to my apartment, I need to walk around 2-3 minutes to go to my apartment. - Yes, But, if I want to book a ride for specific location I need to walk two or three blocks for the same and it's very far sometime. Even though you specify your location, the RAPID vehicle will come far away.
	Mobile Application	- I'm not sure if it's because of the network on-campus, but the app will lag to provide the information to the customer or rider who is going to use the RAPID service. - I think it's moderately easy, especially if you've used an app like that before.
	Ride Comfort	- It's good to ride RAPID. Yeah, I think my experience was good.
RAPID Concerns	Service Availability	- After 2:00 or 3:00 PM because I have other friends who use the RAPID service more frequently than me. So they told me that after 2:00 to 3:00 PM it will be hard to get the RAPID service. - Earlier it was showing me that there are no Via for this location, but then 5 or 15 minutes later, it showed me that you can book the Via right now from this location to the destination.
	Geographic Accessibility	- So I live in Fort Worth by transit. That would get me to the TRE to center port, which I know via goes to center port, but during the summer our classes go till 10:00 PM so there's a little bit of service delivery issue there and I don't think that RAPID goes to Centerport and correct me if I'm wrong, but I would try to do public transit to and from school if I could because. Who wants to be in rush hour traffic? - The only concern is the range of the RAPID in Arlington. So if they're expanding more to nearby cities, the students can travel to other cities via RAPID and will not use Lyft or Uber. - I haven't ridden the RAPID service much, but I think sometimes for some locations it's not available because of some traffic or less number of Via's available.
	Service Cost	- I want to tell you my concern that I want to go from my apartment on the West campus to the central library. That's a short distance. But for that distance, I think it's charging around $3 or $4. I think for an international student it's not convenient because it's very nearby. It should be at least free for on-campus travel. If you want to go far ahead, like downtown Arlington, then it's fine if you're going to charge. But for the on-campus, it should be free. So the people can use it more and know about the RAPID service.
Reason for not riding RAPID	Lack of Accessibility	- I am a staff at UTA and I was going to use the RAPID to come to work one day when I was having some car trouble. But the pickup location was a little bit odd. I was going to have to walk like 3 blocks to get somewhere to where they would be picking up and it was raining and it was cold. And I ended up calling an Uber. So that has been my experience with trying to ride the RAPID.
	Lack of Awareness	- Actually I'm a new UTA student like I have only done one semester at UTA. So I think I probably don't know that it existed for the first four months.

- *RAPID Concerns*

Service availability was mentioned as one of the major concerns mentioned by focus group participants. An SAV user stated that it was tough to get a RAPID SAV ride between 2:00 pm to 3:00 pm on weekdays.

Geographic accessibility was another concern raised by participants. One SAV non-user mentioned that she would be willing to use the RAPID SAV service if it provided rides to CentrePort station like Via. Moreover, another participant stated that more people would opt for using the RAPID if it provided service to nearby cities.

Higher service cost for small distance was one of the major concerns, according to a user participant. An SAV user stated that RAPID charges 3 to 4 dollars a ride for a small distance. He suggested that RAPID should be free for students to travel around the UTA campus.

- Reasons for not riding RAPID

When asked about the primary reasons for not using the RAPID, participants stated they were unaware about RAPID and its operations and used other app-based on-demand services available in the area. One participant mentioned that she tried using the RAPID service once, but when she tried to book RAPID, the pick-up location was very far, and she called an Uber to drop her at the desired destination. Another participant stated that she did not know about the RAPID service operations since she was a new student at UTA.

7.4.2.4 Attitude Towards SAV Technology

- Future SAV Adoption

Price and comfort were mentioned as crucial for future SAV adoption. One participant stated that since Arlington does not have public transit, people are inclined to use app-based on-demand services like Uber because they have no other option. However, in the future, if an SAV service provides comfortable rides at better prices, people will use them regularly. Another participant mentioned that she is optimistic about SAVs being used as a mode of public transport because they are more flexible than traditional fixed route services.

- *SAV Concerns*

Lack of trust in the technology was a major concern for using SAVs. One participant mentioned that she is comfortable riding SAVs but will always be anxious about SAVs doing something unexpected. Loss of connection between autonomous vehicles was another concern mentioned by the participants. One participant stated that she was concerned about the ability of autonomous vehicles to communicate with each other.

- *SAV Benefits*

Increasing mobility options for transportation disadvantaged was a major benefit stated by participants. An SAV user participant mentioned that SAVs increase the mobility options for unlicensed people like international students and people with disabilities. Another participant also highlighted the environmental benefits of using SAVs. She stated it would help reduce the harmful gas emissions in the environment.

- *Future SAV Preferences*

One SAV non-user suggested expanding the service area of RAPID outside on-campus, so people living off-campus can take advantage of the service. Another user who faced issues using the Via mobile application stated that the app was unable to provide accurate information to the customer and insisted on improving the app experience for future SAV service. Moreover, he also suggested providing discounted rides or credits to students who use RAPID frequently around campus.

Table 7-3 Attitudes towards SAV Technology

Theme	Sub-Themes	Example quotes
Future SAV Adoption	Price and Comfort	- I think it's about the comfort first and then the price. I have observed that Uber has become very costly nowadays and I got to know that Arlington is the largest city in the US without public transportation. So people are very used to using Uber and all. But since we have no other option like other modes of public transportation. So we are using Uber. So I think if it comes at a better price and if people are comfortable, I think people are going to use more. - Yes, I do. And I think it's more economical. And then if the vehicles are low emissions or zero emissions, I think that's an added benefit.
	Flexibility	- I actually am really excited about the opportunity for the AVs or SAVs to become a form of public transit. Because it's so flexible versus a fixed route system.
SAV Concerns	Lack of Trust	- I think it's comfortable but you know you need to keep a constant eye on the road. Just that human anxiety that whether it's going to do something wrong. Except that everything is good actually.
	Loss of Connection	- The vehicles are going to talk to each other. For e.g., they're not relying on humans to stop. But I do have a question in my mind about connections. I don't know exactly how they're connected, but if they're connected to the Internet and then that connection is lost. That makes me feel a little uneasy.
SAV Benefits	Mobility for Unlicensed	- If you don't have a license, like some international students because they just came and have to do the procedure for getting the license. So for those people, it will be good to have a service like RAPID. And another thing, like sometimes you don't feel like driving the car or want to go but don't feel like driving. You can request the RAPID ride.
	Environmental Friendly	- So it will be beneficial in terms of reducing the gas emissions and also the other things that people will use it more if it's convenient in terms of comfort and price.
Future SAV Preferences	Wide Service Area	- Also regarding the wide area accessibility, just like I told earlier. I think it would be better if you provide services off campus. I stay off campus. So when I need a ride I look for Uber because the RAPID service is not available. So Uber is the only option for me. So I think if it is available off-campus then it would be fine as most of the people stay around the campus. So I think it would be better if we extend the area of the service.
	Improved Mobile Application	- I think the team can focus on the things like improving the app experience for the user. Like I said earlier, there was some lag in the app while using it because of some specific reasons I don't know. So the app experience would be improved.
	Discounted Rides	- The prices for the on campus rides should be free or there should be some credits available for the students who are like commuting frequently if they're commuting for like 10 times or five times, they at least get some rewards.

7.3 Discussion

This study analyzed user perceptions about the quality of an existing SAV service using data obtained from a ridership experience survey. Additionally, we also analyzed users and potential users perceptions and concerns about the existing SAV services, reasons for not riding the SAVs, their views on what they consider are major benefits and concerns related to future SAVs, and their preferences for future SAV services.

The result from the ridership experience survey indicated that waiting time and pick-up and drop-off location were the lowest rated attributed by survey participants. This means that SAV users were not satisfied with the waiting time and the pick-up and drop-off location provided by the RAPID SAV service. Similarly, the content analysis results indicated that SAV users experienced long waiting times, and the pick-up and drop-off location was very far from the actual location of passengers. To reduce passenger waiting times and encourage the adoption and use of ridesharing, one potential approach would be to expand the fleet size of the services, based on demand (Hörl et al., 2019).

We found that people that did not use the RAPID service faced two significant barriers: lack of accessibility and lack of awareness about the RAPID service. Zhu et al (2020) (Zhu et al., 2020) created the Media Based Perception Model (MBPM) and discovered that social and mass media had a substantial influence on public adoption intentions for autonomous vehicles. Hence, future SAV services could use marketing campaigns to promote the advantages of using the SAVs to increase their customer base.

The survey results suggested that 89% of the respondents agreed to ride the RAPID service again in the future and were highly satisfied with the seating comfort and service cost of RAPID. Similarly, result from the content analysis revealed price and comfort are the two major factors for future SAV adoption, according to the participants. It means that people would be willing to use the SAVs in the future if future SAVs are more comfortable and affordable as compared to existing services. Moreover, we found that participants were excited about the opportunity to ride SAVs as a form of public transportation because it would provide more flexibility as compared to fixed transit. These findings showed that many people might use SAVs in the future if they perceived the technology would make traveling more comfortable and convenient (Lee et al., 2018; Malokin et al., 2021).

Users must have a higher degree of trust to accept the AV technology (Adnan et al., 2018). The survey results indicated that a majority 83% of the SAV users felt safe while riding the RAPID and most of them were willing to ride it again. People's perceptions of autonomous vehicles are improved when they have the opportunity to experience the technology in a secure, safe, and real-world environment (Salonen & Haavisto, 2019). Transit authorities could consider starting pilot projects and deploying AVs in a small region to acquaint the public with the AV technology before integrating them with the current transportation system.

The content analysis of this study showed that environmental friendliness was a major benefit of using the SAVs. Participants believed that SAVs would help reduce gas emissions by allowing ridesharing. This is in line with Woldeamanuel and Nguyen (2018) (Woldeamanuel & Nguyen, 2018), who found that reduction in greenhouse gas emissions is the most important advantage of autonomous cars.

The literature emphasizes the importance of personal attitude toward the successful adoption of SAVs (Asgari & Jin, 2019; P. Liu, R. Yang, et al., 2019). Consequently, we asked focus group participants to share their preferences for future SAVs in the city. Results indicated that both SAV users and non-users are more likely to accept and use future SAVs if the current transportation service expands its geographic reach and capacity. The content analysis result indicates that participants suggested having discounted rides for frequent users to promote the service. Future SAV services could offer discounted rides by providing monthly or quarterly passes to frequent travelers to frequent riders to promote the use of SAVs and increase SAV ridership.

7.4 Conclusion

The general public's view and acceptance of new technology heavily influence how quickly it is implemented and adopted. Therefore, it is essential to assess current travel behavior, challenges, concerns, and preferences connected to AV pilot projects. This study provides crucial insights into people's perceptions, attitudes, concerns, and preferences for future SAVs.

The result of this research indicates that comfort, lower service cost, wider area accessibility are most preferred when it comes to the adoption of SAVs in the future. As a result, future SAV service providers should focus on developing pricing policies for the transit-dependent population by providing discounted rides to regular users of the service. Moreover, the lack of awareness and lack of accessibility are the two major barriers for people to not use SAVs. Consequently, SAV stakeholders can use marketing campaigns to highlight the advantages of using AV technology to attract more customers. Moreover, transit agencies planning to integrate SAVs with current transportation systems should focus on implementing pilot demonstrations to familiarize people with AV technology and provide the opportunity for researchers and policymakers to understand the factors that impact SAV adoption in that area.

There are a few drawbacks of this study: (a) The sample population of this study is homogeneous with all participants being affiliated with UTA. One explanation for this is because RAPID service operations were restricted to the areas near the UTA campus; (b) The sample size of focus group participants was very small as the it was held virtually on the Microsoft Teams platform, and participants with limited technological proficiency were unable to engage in the conversation.

Acknowledgment

The work presented herein is a part of the Arlington RAPID (Rideshare, Automation, and Payment Integration Demonstration) project, which is supported by the Federal Transit Administration (FTA) Integrated Mobility Innovation (IMI) Program funded by the United States Department of Transportation and City of Arlington. The RAPID project is a collaboration among different partners including City of Arlington, Via, May Mobility, and UTA. In addition, special thanks to Dr. Ann Foss, Principal Planner in the Office of Strategic Initiatives at the city of Arlington, for providing great leadership and guidance in the RAPID project.

CHAPTER 8

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

8.1 Conclusion

This study aimed to evaluate the potential opportunities of public-private partnerships for MOD planning. After an extensive literature review of the challenges and lessons learned during the implementation of the Federal Transit Administration (FTA) Sandbox Program projects, this study identified five factors, including 1) fare payment integration, 2) physical infrastructure, 3) schedule integration, 4) data sharing, and 5) app-integration, that assist with establishing a well-integrated public transit system using app-based on-demand technology.

One of the objectives of this study was to explore how people with disabilities perceive and accept autonomous vehicles (AVs) as a technology to improve their mobility. In light of this, a focus group was held in the pre-deployment stage of an SAV pilot demonstration. People with disabilities participated in a virtual focus group to discuss their views on integrating level 4 autonomous vehicles into the current ridesharing service. The content analysis of qualitative data collected in the focus group revealed that accessibility to a well-built environment and health care facilities were among the crucial needs of people with disabilities. In particular, participants with visual impairment were hopeful that future AV services could improve their mobility through advanced apps, booking systems, and vehicle equipment. Focus group participants generally showed a positive perception of the AV service. However, results indicate that disabled people are not interested in riding entirely self-driving vehicles and suggested having a trained operator to assist those who need help while boarding.

Another objective of this study was to create a model that would determine the factors influencing how frequently passengers use the SAV service. In line with this, a brief survey comprising 16 questions was developed to gather data on the purpose of the trip, service attributes, existing modes of transportation, RAPID usage, and sociodemographic factors. Via Transportation, Inc. (the service that offered its platform to book and schedule SAV rides) distributed the survey to anyone who had used the RAPID service at least once. The survey received 252 valid responses in total, and results indicated that most SAV users were young Asian individuals from low-income households with no or limited access to private transportation. Race, the purpose of the trip, waiting time, and vehicle ownership significantly influenced RAPID usage. Furthermore, we found that consumers are more likely to use the RAPID service regularly if they believe it to be beneficial, secure, and easy to use.

This study also aimed to identify the factors affecting the individuals' willingness to ride the SAVs based on the data collected from a comprehensive survey distributed among users and non-users of a self-driving pilot project called RAPID (Rideshare, Automation, and Payment Integration Demonstration) in Arlington, Texas. The survey consisted of 32 questions related to SAV usage and patterns of only users, perception of SAV service by users, users and non-users attitudes towards SAV technology, users and non-users travel patterns, residential accessibility, and sociodemographic characteristics. The IRB at UTA reviewed and approved the survey. A total of 250 valid responses were received after distributing the survey by sharing the survey URL through flyers and emails to the UTA students, faculty, staff, and the general community, notifying users on the Via app, and publishing a link on the City of Arlington's official website. Results revealed that most current users of the RAPID SAV service were young Asian individuals and students from lower-income households with no or limited access to private transportation. After reviewing the existing literature, we developed a conceptual framework with the hypothesized relationship between sociodemographic traits, car ownership, RAPID usage, current transportation services, and RAPID service qualities (comfort and safety). An SEM model was developed in SPSS AMOS using the hypothesis identified in the conceptual framework. Model results indicated that the frequency of using SAVs directly impacts willingness to use SAVs, and sociodemographic attributes of the SAV riders indirectly influence willingness to use SAVs through the mediators, including RAPID usage, existing modes of transportation, and vehicle ownership. Additionally, using the data collected from the comprehensive survey, an ordinal logistic regression model was developed to investigate the influence of attitudinal variables on future willingness to use SAVs. Regression results indicated that users and non-users preferred to ride an AV instead of driving a vehicle. Also, ease of using SAVs positively impacts willingness to use SAVs in the future, and safety concerns about SAV technology negatively impact willingness to use SAVs.

Furthermore, the authors aimed to gain in-depth insights of users and non-users concerns, preferences, and perceptions of RAPID SAVs. Following the study's objectives, personal interviews of seven users and four non-users of the RAPID service were conducted on the Microsoft teams platform to collect information about their travel behavior, perception of the RAPID SAV service, attitudes towards AV technology, and sociodemographic characteristics. All these participants were affiliated with UTA since the RAPID service area focused around the UTA campus. Participants indicated that waiting time, pick-up and drop-off locations, and the ability to make tight turns in intersections are the three major concerns of individuals related to RAPID SAVs. Moreover, interview participants anticipated that SAVs would be more cost-efficient, safer, and environmentally friendly than owner-operated vehicles. Participants who chose not to use the RAPID service did refrain from doing so because it was not accessible or publicly recognized. In line with this, content analysis of the focus group conducted in the post-deployment phase of the project revealed that service availability, geographic accessibility, and higher service cost were the three major concerns of the participants.

This study offers critical insights into individual travel behavior after using SAVs as their on-demand mode of transportation. The outcomes of this study will assist local, state, and federal transit authorities in formulating policies and transportation infrastructure to improve SAV operations in low-density areas. The study's findings also have significant implications for creating SAV services in the future that are suited to the requirements of individuals with disabilities. Moreover, this study recommends strategies for successfully integrating an SAV service with an existing on-demand ridesharing service and provides crucial insights into the attitudes and perceptions of SAV users and non-users.

8.2 Limitations

The limitations of this study include the sample size, the homogeneity of the sample populations, the lack of data on paying customers and cross sectional design, as follows:

Sample size: The sample size of the interview and focus group participants was quite limited because these sessions were conducted virtually technologically disadvantaged individuals were unable to participate. Moreover, the number of responses to the survey was low due to the absence of students on campus during the Covid-19 pandemic. Also, the comprehensive survey was distributed through online channels; hence, only people who visited the specified websites had the opportunity to participate in the online survey.

Homogeneity of the sample population: The findings of this study are constrained by the homogeneity in the sample population most of them being university students. The RAPID SAV service boundary focused around the university campus. As a result, most riders were university students, and the general public had limited accessibility to the SAV service. Moreover, during this study, the RAPID service provided free rides to students encouraging them to use the service more frequently than the general public.

Lack of data on paying customers: This study focused on an SAV service that was provided free to UTA students. A similar study that focuses on the general public who pays for the service is needed to identify the factors affecting their future SAV adoption.

Cross-sectional design: This research was conducted through a cross-sectional design using self-reported questionnaires. Since the study was developed during the ongoing pilot demonstration, people's perception of SAVs is not likely to be anchored. As more people experience the technology under multiple scenarios and the emerging AV technology unfolds, more significant determinants related to the SAV adoption might be discovered.

8.3 Policy Implications

After researching the travel behaviors of users, their attitudes, beliefs, apprehensions, and preferences towards SAV technology. This study provides the following recommendations for policymakers and relevant stakeholders to promote the implementation of new SAV technology in the existing transportation systems:

- The pricing policies of the future SAV services should be tailored for the general public who do not own a car and are part of low-income households, given that SAV technology can increase transportation equity and affordability. Additionally, local governments and authorities can create and implement plans to increase the financial viability of upcoming SAV services, such as subsidizing SAV services for low-income groups.

- An increase in SAV usage develops the trust in AV technology, making it easier or more convenient for them to use SAVs as their primary means of transportation. Policymakers should give rewards and enticing offers to frequent riders to increase SAV adoption.
- People with disabilities and older adults with health issues are other segments of the population that need access to mobility alternatives other than private vehicles. As a result, to successfully introduce SAVs to the market, policy interventions may need to be required to influence older individuals' willingness to adopt AV technology.
- Government and the auto industry should carefully assess public concerns and attitudes regarding AV technology and raise general public knowledge of SAV services in order to encourage SAV adoption. Pilot SAV deployments can provide empirical evidence to demonstrate the reliability of the technology and boost public trust in the technology's safety through testing and riding the AVs on actual roads.

8.3 Recommendation for Future Research

The research work presented in this dissertation can be enhanced through further research. The following, among others, could be potential future developments:

- This study focuses on the integration of SAVs with current microtransit services. Future studies should focus on recognizing the integrations of SAV service into other transportation options as the range of microtransit service models expands over time.
- A majority of the sample population in this study were university students. It is worth noting that employing a sample size from diverse categories of SAV users may result in findings different from the present study.

- RAPID service provided free rides to UTA students during this research. Hence further research can be done to understand how members of the general public who have to pay for the service adopt SAVs.
- Future research can develop a comprehensive set of questions to identify factors affecting the frequency of using SAVs or their acceptance in different parts of the United States, to provide a broader scope of the findings.

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Appendix A

Disability Focus Group Questions

Handitran Service Questions

1. Have you ridden Handitran in the last year? (raise hands)
2. How accessible is the Handitran service, based on your own needs, and what you've seen for fellow riders?
3. Perhaps you could discuss the state of service on Handitran in Arlington.
    a. What has been your experience taking the service in terms of waiting travel time, in vehicle travel time, scheduling the trip?
    b. Booking for the service? Has the call center been adequate?
    c. How far in advance do you need to book?
    d. When do you need to book the return trip?
    e. Is there usually service available when you need it?
4. What has been your experience riding from Arlington to neighboring cities—say, on the Trinity Rail Express? Does Handitran allow you to make that connection?
5. Overall, what elements of the Handitran service work well for you? Are there any areas for improvement?
6. Are there any areas you'd like to be able to go that you can't now?

Via Service Questions

1. Have you ridden Via in the last year? (raise hands)
2. How accessible is Via, based on your own needs, and what you've seen for fellow riders?
    a. How accessibility-friendly has the Via service been, in your experience?
3. Perhaps you could discuss the state of service on Via.
    a. What has been your experience taking the service in terms of waiting travel time, in vehicle travel time, scheduling the trip?
    b. Booking for the service? Have you tried the app, or booked by phone?
        i. Discuss your experiences with either method.
    c. From experience, how far in advance do you need to book in order to obtain a ride?
    d. Is there usually service available when you need it?
4. When you have needed to take Handitran instead of Via, what were the reasons you used Handitran instead of Via?
5. What has been your experience riding from Arlington to neighboring cities—say, on the Trinity Rail Express? Does Via allow you to make that connection?
6. Overall, what works well for you on Via? Are there any areas for improvement?
7. Are there any reasons you need to use Handitran over Via, or Via over Handitran?
8. If you were to design the new automated vehicle transit service to service some of the trips you now take on Handitran, how could we do that?
9. Are there any areas you'd like to be able to go that you can't now?

Campus Shuttle Service Questions

1. Have you ridden the campus shuttle, including the late night golf cart service in the last year? (raise hands)
2. How accessible are the campus shuttle and golf cart services, based on your experience?
3. Perhaps you could discuss the state of service on the campus shuttle and golf cart services at UTA.
    a. What has been your experience taking the service in terms of waiting travel time, in vehicle travel time, scheduling the trip?
    b. Booking for the service?
    c. How far in advance do you need to book (if at all)?
    d. Is there usually service available when you need it? Late at night?
4. Overall, what elements of the campus shuttle and golf cart services work well for you? Are there any areas for improvement?
5. Are there any areas you'd like to be able to go that you can't now?

Proposed SAV Service Questions

1. Looking at the map of the proposed service, would this be helpful to your needs?
2. What would you change about it?
3. What areas would you need to go that are not included in the current draft plan?
4. How well are you able to use the app booking system, and what features would we need to include to ensure you are able to use it?
5. The service is designed to be free to students, but other community members would need to pay, like Via. Have you had any problems booking and paying for Via that we should know about?
6. Do you require assistance to board the vehicle? If so, what kind?
7. How about your approach to the boarding location? Have you had any challenges approaching Via, Handitran or the Campus shuttle services that we can learn from as we develop the AV service?
8. This service is also designed to connect with Via and the Campus Shuttle & Golf Cart services. What can we do to make sure you have a smooth connection. Let's think, especially, about how to make that connection work for your own disability.

Public Involvement Questions

1. Perhaps you could discuss your previous experiences communicating your needs to Handitran? To Via?
2. What motivated you to serve as an adviser or advocate on disability issues?

3. Discuss your role as an advisor or advocate on disability issues. Have you been able to work for service improvements? Do you have any feedback on this process?
4. Thinking about the big picture, how is transportation in Arlington for people with disabilities? What services work well? Are there any areas with room for improvement?
5. Do you have recommendations for ensuring we receive feedback on the proposed AV service from those with accessibility needs?”

Appendix B

SAV Users Survey

1. What was the purpose of your trip on RAPID today?

- o Going to work
- o Going to school
- o Going shopping
- o Going to a medical place
- o Going to social and/or Recreational places
- o Going to daycare/Childcare
- o Returning home
- o Others

2. How long did you wait for the AV vehicle to arrive after requesting a ride?

- o Less than 5 minutes
- o About 5- 10 minutes
- o About 10-20 minutes
- o About 20-30 minutes
- o More than 30 minutes

3. Please share your opinion of your ride today.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Not applicable for this ride
- Booking and scheduling my RAPID trip using the Via app was easy						
- Booking and scheduling my RAPID trip through the call center was easy						
- The price for riding RAPID was reasonable						
- The waiting time was reasonable						
- The pickup and drop off locations were convenient						
- Boarding the vehicle was easy						
- The seats in the vehicle were comfortable						
- The climate control in the vehicle was appropriate						
- The speed of the vehicle was reasonable						

- I felt safe when riding RAPID						
- I felt safe while sharing the vehicle on my RAPID ride with other passengers						
- I would ride RAPID again in the future						

4. Which of the following transportation services have you used in the past? Select all that apply

- o Via
- o Handitran
- o Milo AV Pilot
- o Drive.ai AV Pilot
- o UTA Transportation
- o Public transit in another city
- o I haven't used public transit before

5. Please tell us about your RAPID ride compared to your previous experience with AV services through the following questions.

	Much improved	Improved	No improvement	Worse	Much worse	I don't know
- Service area of RAPID						
- Trip cost of RAPID						
- Safety of riding on RAPID						
- Convenience of trip with RAPID						
- Waiting time on RAPID						
- Travel time on RAPID						
- Overall experience of riding RAPID						

6. What is your usual mode of transportation?

- o Private vehicle
- o Private app-based ride services, such as Uber or Lyft
- o Via Service
- o Handitran service
- o UTA transportation
- o Walking/biking
- o RAPID service
- o Others

7. How often have you ridden RAPID so far?

- This is my first time
- This is my second time
- About once per month
- About twice per month
- About once per week
- More than two times per week

8. What is your age group?

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 and above

9. What is your home zip code?

10. What gender do you identify with?

- Female
- Male
- Other
- Prefer not to answer

11. Are you currently a UTA student?

- Yes
- No

12. With which racial group do you most identify?

- American Indian or Alaska Native
- Native Hawaiian or Pacific Islander
- Asian
- White
- Black or African American
- Other

13. With which ethnicity group do you most identify?

- Hispanic
- Non-Hispanic

14. What was your household income last year?

- Less than $20,000
- $20,000-$34,999
- $35,000-$49,999
- $50,000-$74,999
- $75,000-$99,999
- $100,000 or more

15. How many vehicles are available to you and members of your household for daily travel?

- 0
- 1
- 2
- 3 and more

16. Do you have any further feedback for us to consider about our AV service Comments/Suggestions?

Appendix C

SAV Users and Non-Users Survey

1. Which statement best describes your status? (check ALL that apply).

- I am 18 years or older
- I live, work, and/or study in Arlington
- None of the above

2. Please select the autonomous vehicle (AV) services that you have ridden in the City of Arlington (check ALL that apply).

- RAPID
- Milo
- Drive.ai
- I have never used an autonomous vehicle in Arlington

3. How many times you have ridden RAPID in Arlington?

- One time
- Two times
- Three to four times
- Five to Six times
- More than Six times

4. How do you usually access a RAPID pick-up point? (check the option that you use most often)

- Pick Up from Home, school, or work location
- Walking or using a mobility device such as a wheelchair
- Bicycle/Scooter
- Via Service
- UTA Transportation Service
- Handitran Service
- Taxi/Uber/Lyft
- Household vehicle (car/truck)
- Other

5. What is the typical purpose of your trips on RAPID? (check ALL that apply).

- Work
- School
- Shopping
- Medical
- Social and Recreational
- Others

6. After completing your trips on RAPID, do you usually use another transportation mode to reach your destination?

- Yes
- No

7. What transportation mode do you usually use after your RAPID ride to reach your destination?

- Walking or using a mobility device such as a wheelchair
- Bicycle/Scooter
- Via Service
- UTA Transportation Service
- Handitran Service
- Taxi/Uber/Lyft
- Household vehicle (car/truck)
- Other

8. Please rate your experience riding RAPID in the following areas by using a scale of 1 to 5 (1: very Poor, 2: Poor, 3: Average, 4: Good, 5: Excellent, 6: I do not know)

	Excellent	Good	Average	Poor	Very Poor	I don't know
- Waiting time						
- In-vehicle travel time						
- Ridership cost (reasonable trip fare)						
- Availability of RAPID at the time I need it						
- Access to accurate information about the RAPID service area, days, and hours of operation						
- Ease of payment through the RAPID app						
- Ease of booking process, trip planning and scheduling						
- Ease of boarding RAPID at the pickup and drop off locations						
- Access to desirable destinations						
- Adequate number of seats per vehicle						
- Comfort of seats and climate control						
- Feeling of safety due to presence of onboard human attendant						

- Ride comfort due to the vehicle traveling at a reasonable speed						
- Feeling of safety about ability of the AV to interact with other vehicles on the road						
- Feeling of safety related to sharing the RAPID ride with other passengers						
- Feeling of comfort due to cleaning protocols while sharing the RAPID ride with other passengers						
- Ability to book RAPID rides through call center						
- Ability to book Via ride and AV ride in the same app						

9. Do you have a disability that requires you to travel with a wheelchair or other type of assistance?

- o Yes
- o No

10. Please rate your experience riding RAPID in the following areas by using a scale of 1 to 5 (1: very Poor, 2: Poor, 3: Average, 4: Good, 5: Excellent, 6: Not applicable)

	Excellent	Good	Average	Poor	Very Poor	Not applicable
- Availability of the wheelchair accessible vehicle at the time I need it						
- Ease of boarding RAPID for people with physical disabilities						
- Ability to request a ride on RAPID for people with visual impairments						

11. If you are a student at UTA, to what extent was the free ride for UTA students available on RAPID important in your decision to ride this service?

- o Not at all important
- o Of little importance
- o Of average importance
- o Very important
- o Absolutely essential
- o I am not a UTA student

12. Which statements describe the main reasons you rode the RAPID? (check ALL that apply).

- I rode RAPID to try the service
- I rode RAPID because UTA students get free AV rides
- I rode RAPID because I heard from others that they enjoyed their AV ride
- I rode RAPID to accompany my friend/family on an AV ride
- I rode RAPID because it was the most convenient option for my trip

13. If you have not ridden RAPID yet, please answer which statements describe the main reasons for not riding RAPID? (check ALL that apply). If you have ridden RAPID skip this question and go to question 14.

- I did not know about RAPID
- RAPID did not provide service to my destinations
- RAPID did not provide service in the times that I needed a ride
- I did not feel safe riding RAPID
- I did not know how to book or pay for a ride
- I felt the RAPID service may not be as convenient as another mode of transportation
- Other reasons

14. Please rate your agreement with the following statements in the following areas by using a scale of 1 to 5 (1: Strongly disagree, 2: Disagree, 3: Neutral, 4: Agree, 5: Strongly agree, 6: I don't know)

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	I don't know
- AVs can increase the convenience of travel						
- AVs can make my trips easier since I will no longer need to look for parking						
- Cyber security is a concern						
- Confusion among human drivers and AVs on the streets is probable						
- AVs can make transportation safer						
- I would recommend AVs to my family and friends						
- I support AV technology						
- I prefer riding an AV to driving myself						

15. If the RAPID service continues to provide rides in Arlington, how likely would you be to ride the service?

- Very likely
- Somewhat likely
- Neither unlikely nor likely
- Somewhat unlikely
- Very unlikely

16. According to your answer to question 15, please tell us what factors affect your response to question 15 Comments/Suggestions:

17. How often do you usually use the following modes of transport?

	Never	Less than once per month	Once per month	Two to three times per month	Once per week	Two or three times per week	More than three times per week
- Car							
- Via Rideshare service							
- Private app-based services such as Uber/Lyft							
- Handitran service							
- UTA transportation services							
- Walking/biking							
- Trinity Railway Express							

18. Please provide the following information about your home, work, or school locations. (Please choose the one most commonly visited location in a typical week)

Location	Enter Zip Code
Home	○
Work	○
School	○

19. Please indicate the approximate driving distance (in minutes) from your current residence to

different errands (by car)

	Less than 5 minutes	5-10 minutes	10-15 minutes	15-20 minutes	More than 20 minutes
- Closest grocery store or department store (such as Walmart or Target)					
- Closest shopping mall					
- Closest restaurant or fast-food place					
- Closest drugstore					
- Closest health care provider					
- Closest place to exercise (e.g., a gym or a park)					

20. What gender do you identify with?

- o Male
- o Female
- o Other/Nonbinary
- o Prefer to not answer

21. Please indicate your age group from the below list.

- o 18-24
- o 25-34
- o 35-44
- o 45-54
- o 55-64
- o 65 and above

22. With which racial group do you most identify?

- o American Indian or Alaska Native
- o Asian
- o Black or African American
- o Native Hawaiian or Pacific Islander
- o White
- o Other

23. With which ethnicity group do you most identify?

- o Hispanic
- o Non Hispanic

24. What is your educational background? Please check the highest level attained.

- Prefer not to answer
- Some grade/high school
- High school/GED
- Some college/technical school
- Associate's degree
- Bachelor's degree
- Graduate or professional degree (e.g. MS, PhD, MBA, JD, MD, DDS, etc.)

25. Which statement best describes your current employment? (check ALL that apply).

- I work full-time
- I work part-time
- I am a student
- I am a homemaker/unpaid caregiver
- I currently do not work/I am retired/looking for work

26. What statement best describe your current working or studying status?

- I fully work/study from home
- I partially work/study from home
- I fully work/study from my work/school place

27. What was your household income last year?

- Less than $20,000
- $20,000-$34,999
- $35,000-$49,999
- $50,000-$74,999
- $75,000-$99,999
- $100,000 or more

28. Do you have a valid driver's license?

- Yes
- No

29. How many vehicles are available to you and members of your household for daily travel?

- 0
- 1

- 2
- 3 and more

30. Do you have any of the following long-lasting conditions?

	Yes	No
(a) Blindness, deafness, or a vision or hearing impairment?		
(b) A condition that substantially limits one or more physical activities such as walking, climbing stairs, reaching, lifting, or carrying?		

31. What assistance, if any, do you need to board public transit?

- Ramp
- Patient Care Assistant (PCA)
- Lift
- Service animal
- Others
- None

32. Do you have any further thoughts to share with us about RAPID? Comments/Suggestions:

Appendix D

Structured Interview Guide

Personal Travel Behavior

1. What means of transportation do you usually use for different purposes/trip destinations including work, education, grocery shopping, shopping cloths/electrics, health care, recreational trips?
2. What means of transportation do you usually use for different parts of the Arlington including: UTA campus area, UTA off campus area, Arlington Downtown, far from Arlington Downtown, adjacent cities?
3. How frequently do you usually use different modes of transportation and for what purposes?
4. What is the average travel time of different transportation modes you use for different purposes?
5. How frequently do you use the following public transportation modes in Arlington? RAPID, Via transportation, UTA shuttle service, app-based on-demand services such as Uber, Handitran, Trinity rail, other if available?
6. What is your most usual mode of transportation? How often do you use this mode in a typical month/week?
7. Why do you use this mode of transportation?
8. Are there certain purposes for which you only use this mode? If so, which and why? Otherwise, why not?

Perception of RAPID SAV

1. Purpose for using RAPID.
2. Trip origin location when using RAPID.
3. Trip destination location when using RAPID.
4. Trip waiting time when using RAPID.
5. Trip length (in vehicle minute) when using RAPID.
6. Trip fare when using RAPID?
7. How often do you share a ride with someone else you don't know on RAPID?
8. How do you get to and from your RAPID pick and drop-off locations? Please tell us about the RAPID application.
9. Tell me about your comfort riding RAPID

Attitudes towards AV Technology

1. What are your main concerns about AVs technology? (such as safety, security, etc.)
2. What are the main challenges that must be tackled to integrate AVs into existing traffic systems?
3. What are the main benefits of the AV technology (such as social, economic, and environmental impacts)?

4. How do you personally evaluate the development of AVs in future?
5. Will you accept the AVs in future? If yes, to what extent? Will you use it as your usual/main mode of transport? If not, why? For what purposes you will use the AV technology in future?
6. Would you leave your commonly used public transport service in favor of a new AV one?
7. In what condition will you use an SAV instead of a private car? Cheaper cost? Availability? Flexibility? Reliability?

Personal Socioeconomic Characteristics

1. Where do you live (e.g., apartment, house, townhouse, etc.)?
2. Where is it located?
3. How crowded is your place of residence in terms of traffic congestion?
4. What facilities and services can be found there?
5. Do you like living there? If so, why? If not, why
6. How old are you?
7. Do you have a driver's license?
8. Do you have your own car? How many cars are available in your household?
9. Are you a student?
10. Are you employed? Part time or full time?
11. What is your last education degree?

Appendix E

Post-Implantation Focus Group Questions

RAPID Service

1. How many of you have ridden RAPID, the self-driving vehicle service in Arlington?
2. If you have not ridden the service at all, perhaps you can describe your reasons for not using the service?
3. For the students who have ridden RAPID, did you ride RAPID when it was free for you to ride (March 23, 2021, to March 18, 2022)? (Raise hands)
4. Also, for the students who have ridden RAPID, have you ridden RAPID after March 18, when you received a reduced fare of $1 off? (Raise hands)
5. For RAPID users, perhaps you could discuss the features of service on RAPID. For example, can you describe your experience with the following subjects?

    a. What has been your experience taking the service in terms of waiting travel time, door-to-door travel time, scheduling the trip?
    b. What has been your experience booking for the service? How was your experience of booking a ride by app?
    c. From your experience, how far in advance do you need to book to obtain a ride on-time?
    d. Is there usually service available when you need it?
    e. If not, are there certain times of day, or weekdays when you have had the most problems booking a ride?
    f. What has been your experience about the pickup and drop off locations when riding with RAPID?
    g. Have you ever experienced a shared ride with others when riding RAPID?
    h. If yes, what has been your experience sharing a RAPID ride with others?
    i. What has been your experience taking the service in terms of the vehicle comfort and convenience (e.g., getting on and off the vehicle, seats, temperature, space, noise).
    j. What has been your experience taking the service in terms of the safety (e.g., vehicle speed, turnings, handling any unpredicted incidents)?

6. For RAPID users, what has been your experience riding RAPID inside the service area—what are the most common origins/destinations of your RAPID ride?
7. For RAPID users, what are your most common trip purposes for RAPID rides? (Get to classes or work)? Has it been useful for getting to a destination by the time you need to be there?
8. For both RAPID users and non-users, how accessible is RAPID, based on your own needs, or riders you may have talked to? Perhaps you can discuss about the spatial and temporal accessibility.
9. For both RAPID users and non-users, overall, what works well for you on RAPID? Are there any areas for improvement?

10. For both RAPID users and non-users, are there any areas you'd like to be able to go that you can't go now?
11. For RAPID non-users, perhaps you could discuss your previous experiences riding Via or the University Transportation Services?

AV/SAV Technology Perception

1. How do you think that shared autonomy vehicle (that we call it as SAV service, such as RAPID service); can compete with other public transit modes such as on-demand ride services (e.g., Via) and fixed-route transit (bus)?
2. To what extent you feel SAV can be useful for daily mobility (e.g., using SAV can make your daily mobility quicker, more effective, or cheaper, being able to travel when tired/sleepy, being able to study/work when traveling, enjoying the trips)?
3. To what extent you feel SAV can be easy to use for daily mobility? (e.g., easy to book a ride, easy to learn about, easy to use by people with disabilities)?
4. Do you have any concerns about the SAV service (e.g., interacting with conventional vehicles, pedestrians, cyclist, failure of the software and system of this technology, data privacy, sharing a ride with strangers, hacking of the vehicle's computer systems)?
5. Are there any are benefits of the SAV service (e.g., reduce crashes, reduce traffic congestion, lower vehicle emissions, reduce the stress of driving)?

Intention to Adopt SAV

1. If shared autonomous vehicles (SAVs) like RAPID service were widely available, how would you and your household use these services and how would they impact the vehicle(s) you currently own (e.g., keep current vehicles and not use any driverless services, keep current vehicles, but also use these driverless services whenever needed or convenient, get rid of one (or more) household vehicles and use driverless services instead)?

General Questions

1. Do you have recommendations for ensuring we receive feedback on the next phase of the RAPID service from students, faculty, and staff?
2. Do you have any final thoughts on the RAPID service or recommendations for the future of the service?