Examining Data Needs and Implementation Process of AV-Based Microtransit Service: A Case Study in Lake Nona

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Disclaimer

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16. Abstract

The development of Autonomous vehicles (AVs) has brought many opportunities but implementing AV-based public transportation services has numerous unforeseen issues. One primary research gap is that existing studies on AV transit systems consist of predictions and speculation without actual cases and data support. Another issue is that a measurement tool is needed to quantify the impact of an AV project. Therefore, this research has developed a holistic, user-friendly AV-Based Microtransit Effectiveness Evaluation Framework (the AVEE Framework). The AVEE Framework uses an "element – criterion – pillar" rating system, examining various aspects of an AV-based microtransit system, including policy and government support, infrastructure and technology, service and management, financial sustainability, and ridership and community impact. The purpose of developing the framework is to facilitate vendors to select AV projects to invest in or enable decision-makers to learn and compare AV projects' performances during or after the implementation phase. Besides creating the framework, this research has provided a complete literature review of existing AV shuttle programs worldwide and other assessment indices of urban or AV-related projects. The research team has also conducted a community survey in the Lake Nona neighborhood, Orlando, and then applied the AVEE Framework to the Move Nona AV shuttle program as a demonstration.

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Executive Summary

The breakthrough in autonomous vehicle (AV) technology has been spurring the advancement of the transportation industry. Potential advantages like enhancing transit services and reducing labor and operation costs have intrigued many decision-makers and investors to dive into this possible blue ocean (Litman, 2021; Othman, 2021). Nevertheless, challenges and innovations often coexist. In public transportation, for instance, the question of how to quantify a proposed or deployed AV project's effectiveness has been demanding due to the lack of a comprehensive measuring tool or a unified standard, making impact assessment imprecise and sometimes perplexing. Therefore, it is vital to investigate the abovementioned issue as well as others and to seek solutions by analyzing literature and real-world cases.

In line with the procedures of developing the Effectiveness Evaluation Framework of AV-based microtransit projects, the research comprised the following steps and components:

First was a summary of all operating AV-based microtransit services in Europe, North America, Asia, and Australia. (This assessment does not include private, on-demand services operated using conventional passenger vans, such as those being used by Waymo.) The main result of this summary is that almost all former and current AV transit services have been pilot/demonstration projects in early stages. Shared characteristics included a short implementation period of around two years, a small fleet owning two to four low-speed (less than 15 miles per hour) autonomous minibuses/vans, and reliance on fixed routes. Meanwhile, most studies related to those AV transit programs emphasized via surveys users' perceptions and willingness to ride, suggesting a necessity to combine the findings into assessing actual impacts.

The second part was a literature review of some professional, widely accepted tools for evaluating AV systems' impacts or readiness as well as other closely related urban projects, utilizing their concepts and essences to build a new framework. For example, KPMG's Autonomous Vehicles Readiness Index, FDOT's Connected and Automated Vehicles Business Plan, and the United Nations' Sustainable Development Goals Assessment Tool all contributed to the design of the structure, selection of measuring criteria, and visual representation of the scores and outcomes.

Third, the research introduced the AV-Based Microtransit Projects Effectiveness Evaluation Framework (referenced as the **AVEE Framework**). As a holistic, user-friendly instrument, it would equip decision-makers and the framework users state and nationwide to quantify the political, economic, technical, and social impacts of similar AV programs conveniently and scientifically. The scoring system adopted a bottom-up "element – criterion – pillar" structure: users could start by rating the element scores and then use the results to calculate criteria and pillar scores (on a scale of zero to five). A higher score has a more positive implication, suggesting that an aspect of the selected AV project has a good performance or favorable influence based on the evaluation. The five pillars were: Policy and Government Support, Infrastructure and Technology, Service and Management, Financial Sustainability, and Ridership and Community Impact.

As stated earlier, various nations have been taking similar approaches in testing AV transportation, highlighting the necessity of studying one of such projects that could epitomize similar systems elsewhere. To address this research gap, we originally intended to study the Local Alternative Mobility Network (LAMN) project in Orange County, FL, funded by a $20 million Better Utilizing Investments to Leverage Development (BUILD) grant from the USDOT. The LAMN project planned to build a large-scale, AV-based microtransit system in Lake Nona, Orlando. However, as of December 2022, the County has not yet received the funding; thus, the research team refocused on an existing AV shuttle program, Move Nona, in the same community. Invested by a private developer, Tavistock Development Company, Move Nona served as a demonstration program preparing for the LAMN buildout. Albeit smaller in investment scales, route coverage, and fleet size, analyzing Move Nona could still provide valuable experiences for future AV transit system development and explorations.

Regarding the case study, the research team conducted an existing site and demographic analysis, two field reviews, and a community survey (onsite and online, ID: IRB202201461). The results showed that Lake Nona was a well-planned, fast-growing neighborhood with high income, educational attainment, and ownership and dependency rates of automobiles. The community survey received 223 responses, with 57.4 percent of responders saying they have used the AV shuttle before, while the rest have seen one. Their answers revealed that most respondents are willing to try new technology and products and positively perceive the AV shuttle's aspects, including ease of use and safety. Another finding was that the residents only used the AV shuttle occasionally. Rather than a routine transportation method, they tried one or two times for leisure or curiosity, implying the limits of a demonstration project.

Lastly, the research team applied the AVEE Framework to the Move Nona program. The pillar scores (out of five) were:

1. Pillar 1 – Policy and Government Support: **4.65**
2. Pillar 2 – Infrastructure and Technology: **4.54**
3. Pillar 3 – Service and Management: **3.54**
4. Pillar 4 – Financial Sustainability: **1.25**
5. Pillar 5 – Ridership and Community Impact: **2.65**

The first two scores indicated that statewide and regional stakeholders were prepared to provide governmental and infrastructure support for AV implementation; however, the other pillar scores indicated that the slow travel speed, harsh braking, financial sustainability (e.g., high capital cost), and low transit system efficiency (e.g., passengers per vehicle-miles travelled) of Move Nona could hinder it and similar AV shuttles systems from becoming a long-term public transportation option. By further analyzing the scores, the UF team constitute the following recommendations:

1. Keeping an AV shuttle's speed of about 30 mph, promoting a smartphone app exhibiting real-time maps and schedules, adding more AV stops (or offering door-to-door service), and improving the smoothness of the ride may fulfill passengers' primary expectations.
2. According to Florida's experience, it is essential to have lucid, transparent transportation laws and regulations when promoting AV transit programs. Also, establishing a designated AV department or office may better enforce the implementation.
3. New AV transit programs may consider using AV shuttles models that have been proven safe and reliable in other regions/neighborhoods, to avoid lengthy road/performance tests.
4. When selecting a site to accommodate an AV transit system, one should notice how much infrastructure modifications are required, e.g., expanding an extra lane will be costly.
5. Some AV industry pioneers, like BEEP, have accumulated multiple years of experience of operating and maintaining the AV service, which can be shared with new AV operators.

Table of Contents

List of Figures

List of Tables

Chapter 1. Introduction

1. Background

In recent years, autonomous vehicles (AVs) have advanced from conceptual devices to prototypes and are being tested on public roads with freight and passengers, particularly for level three and above, i.e., with automated driving features replacing drivers, based on the Society of Automotive Engineers (SAE) standards for driving automation (National Highway Traffic Safety Administration, n.d.; SAE, 2021). This technology promises to enhance transit services, reduce operation costs, and attract new riders, but integrating it into the public transportation system is complicated due to unforeseen issues and controversies in the planning and deployment process, such as safety concerns and regulatory gaps (Othman, 2021). Furthermore, there is also a lack of quantifiable benefits or impact analyses from existing AV-based microtransit services.

Many studies have speculated the impact of AVs, especially in traffic safety enhancement and passenger mobility improvement, given today's decreasing travel costs and increased convenience (Kohlstedt, 2017; National Association of City Transportation Officials, 2017; Soteropoulos et al., 2019). While one may believe that AVs are the hope for enhancing road safety, reducing freight costs, minimizing city parking, and improving mobility, considerable doubts still exist (Bloomberg Philanthropies & the Aspen Institute, 2017). Questions remain, like whether microtransit AVs would increase travel demand, thus exacerbating congestion, and how they affect public transit ridership (Fagnant & Kockelman, 2013; Weinberg, 2017).

Moreover, recent studies on AV mobility have shown that AV deployment in urban areas may reduce 80 percent of private cars, but this would only be possible if AVs appeared in a rideshare scenario (Union Internationale des Transports Publics, 2020). In response, manufacturers have been prone to produce vans or minibuses with passenger capacities of around six to 15, which allowed AVs to serve as either fixed-route shuttles or more flexible, on-demand microtransit (EasyMile, 2017; Navya, 2017). Various studies have explored possible cases of using AV-based transit methods to provide first- and last-mile connections to existing public transit services and community circulators, as well as to locations unnecessary or unsuitable for building traditional transportation services (Mantri et al., 2020).

Meanwhile, some government agencies and research institutes started to set up relevant guidelines and assessment criteria for AV programs, but most studies were still speculative or rudimentary. For example, Mobility e3 LLC has proposed guidance for transit agencies and communities on launching low-speed AV pilots in the public transportation system (Coyner et al., 2021). In 2019, the Nevada DOT announced a framework to assess a dedicated AV facility's potential ridership, design standard requirements, and financial benefits.

Nevertheless, the literature has implied a critical research gap in that most existing studies mainly consist of predictions and speculation without real-world cases and data support. Besides, albeit relying on theoretical underpinnings, select guidelines and frameworks lacked documentation of applied implementation issues, challenges, and lessons learned through a test bed (Turnbull et al., 2022). To this point, there is an urgent need to investigate a non-hypothetical case of an AV-based microtransit project in the United States and to develop a user-friendly method to measure the AV project's impact comprehensively before the nation deploys AV systems widely. **Table 1-1** below includes definitions of AV-related terms.

Table 1-1

Definitions of AV-Related Key Terms

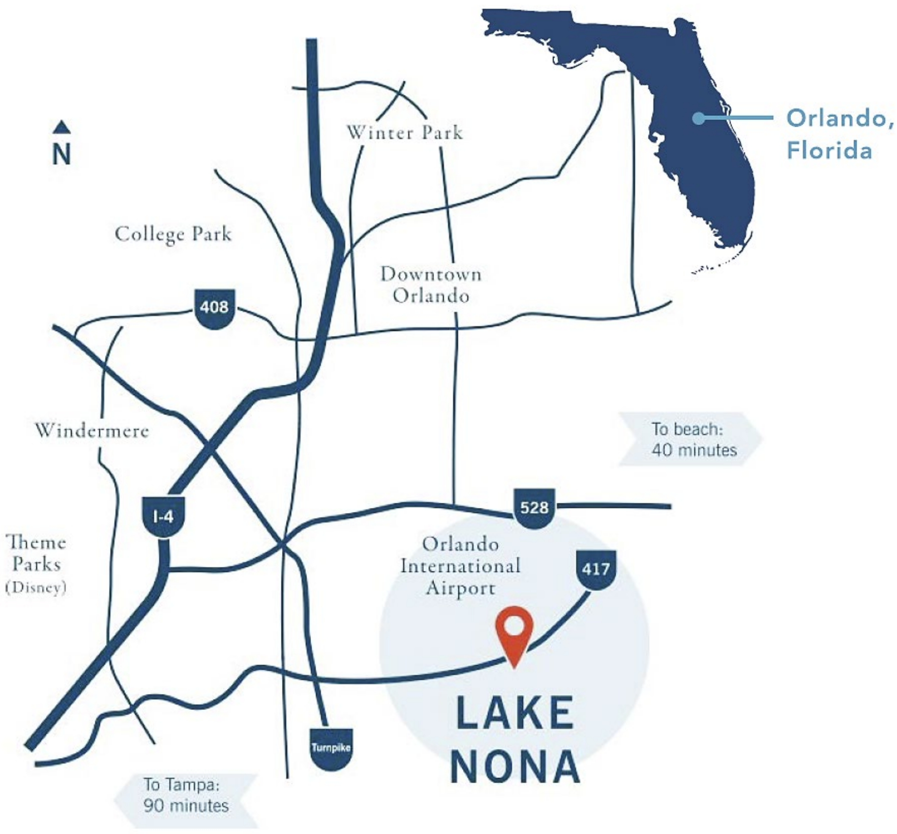
Key Term	Definition
Autonomous Vehicle	AV, also known as a driverless or self-driving car, is a vehicle (which can be electric) capable of sensing its environment and moving with little or no human input (SAE, 2021; Lake Nona, 2020).
Microtransit	Microtransit is an IT-enabled, small-scale, shared transit service that can offer either on-demand or flexible service, and which operates on fixed or flexible routes (Slosky, et al., 2022).
AV-based microtransit	A microtransit service facilitated by AVs.
AV Shuttle	A shuttle that uses AVs to transport people back and forth from one point to another. As a type of AV-based microtransit service, most AV shuttle programs in the United States use electric vehicles that can hold six to 12 passengers (WSP, 2021; Allen, 2022).

2. Opportunities: Move Nona AV Shuttle Program

In Florida, a precious opportunity has arisen to document the challenges and opportunities present during an AV-based microtransit system's planning and implementation processes. In November 2019, USDOT awarded Orange County a $20 million Better Utilizing Investments to Leverage Development (BUILD) grant. The grant would create a Local Alternative Mobility Network (LAMN) to provide better mobility options that reduce car dependency in southeast Orlando's Lake Nona community (**Figure 1.1**). Its main objective was to support planning, designing, and constructing critical infrastructure components like shared mobility lanes and twenty self-driving vehicles (Orange County, 2019).

Figure 1.1

Location of the Lake Nona Community



Note. From *Lake Nona* [Digital Image], by Tavistock Development Company, 2019 (https://images1.loopnet.com/d2/laQIbv0KbPKX-FoJ2L7pKawhQ9pfs3a6er2wGT37xZk/Lake%20Nona%20Greenwood%20Master%208%202021.pdf)

Although one of the initial research purposes was to examine the BUILD Grant LAMN project, which could exemplify Florida's endeavor to automate its public transit system, unfortunately, the grant's funding was not ready when drafting this report (December 2022). As a result, the case study's target has become the Move Nona AV shuttle program (**Figure 1.2**), the only active AV service in the area. Move Nona's sponsor is the neighborhood investor and developer, the Tavistock Development Company. Beep, a local autonomous mobility solutions provider of driverless shuttles, oversees daily operations, staff training, and maintenance. After three years of safe and successful services that have carried over 470,000 passengers, Move Nona has testified its potential to broaden people's travel options. (Tavistock Development Company, 2019; Visit Orlando, n.d.).

Figure 1.2

A Move Nona AV Shuttle Operating in Lake Nona

Note. From *Move Nona* [Photograph], by BEEP, n.d. (https://ridebeep.com/location/move-nona/).

At the same time, Lake Nona (see **Figure 1.3**) per se is a typical fast-growing suburban community built from scratch with compactly developed single-family and multi-family housing, anchored by a 650-acre health and life sciences park (the Lake Nona Medical City) in its core. The case of Lake Nona could epitomize similar new residential developments in Florida and the rest of the nation searching for innovative public transit methods.

Figure 1.3

Lake Nona's Town Center and Residential Area

Note. The photograph (top) is from *Lake Nona Town Center*, by Lake Nona, 2020 (https://www.lakenona.com/thing-place/lake-nona-town-center/). The photograph (bottom) depicts the housing patterns of the neighborhood. From *Laureate Park,* by One Creative Media, n.d.

However, it is worth to point out that the Move Nona AV shuttle program does not benefit from the same range and magnitude of improvements that the BUILD Grant LAMN project would have, but it does offer an opportunity to examine an established, fully operational AV shuttle deployment in the same service area. With this in mind, the UF study team focused its research on assessing the Move Nona deployment, recognizing that some aspects of its operation (speed, reliability, customer acceptance) may perform worse than if all of the improvements envisioned in the BUILD Grant program were in place.

3. Research Purpose and Objectives

Section 1.1 identified the main research gaps in the AV-based microtransit literature, deriving the following fundamental research questions:

1. What criteria can be used to measure an AV-based microtransit system's effectiveness?
2. How to develop a tool to support decision-makers comparing proposals or bids of different AV-based microtransit programs before implementation?
3. What are the real public perceptions of an AV shuttle? What features, e.g., design, speed, and cabin size, do people like or dislike about it?
4. What are the reasons motivating or discouraging people from using an AV service?
5. What can the potential AV investors or decision-makers learn from the assessment?

On top of the research questions, the research objectives are as follows:

1. To examine primary implementation challenges and real-life benefits and drawbacks of an AV-based microtransit system in the United States using the case study of the Move Nona AV shuttle program in Orlando, FL.
2. To develop a comprehensive evaluation framework for AV-based microtransit programs' effectiveness based on literature and standards, facilitating decision-making by investors or governments.
3. To customize and design different versions of the framework fulfilling various users' needs throughout an AV project's launch process.
4. To utilize the Move Nona program as a sample for testing the framework and obtaining the quantified results.
5. To summarize lessons learned from the research, build knowledge, and share experiences for the future.

4. Research Approach and Tasks

The entire research project contains six tasks, collated into six deliverables/reports (submission dates are in parentheses, and this report is Task 5):

1. *Task 1.* Review and Analysis of Existing and Planned Autonomous Vehicle (AV) Transit Technology Projects and Studies (2021/09/30)
2. *Task 2.* Baseline Data Collection, Analysis of Lake Nona Community, and the Evaluation Framework Development of AV-Based Microtransit Services (2022/01/31)
3. *Task 3.* Summary of Lessons Learned from Developing the AVEE Framework and the Move Nona System's Implementation and Evaluation (2022/08/31)
4. *Task 4.* Community Survey Development, Deployment, and Analysis of the Move Nona AV Shuttle Program (2022/09/30)
5. *Task 5.* Draft Final Report (2022/10/31)
6. *Task 6.* Final Report (2023/01/15)

By modifying and integrating the first four task reports/deliverables, the following part of this final report comprises seven chapters, organized as follows:

1. *Chapter 1:* Introduction of the Lake Nona research and report
2. *Chapter 2:* Literature review of AV-based microtransit programs (adapted from Task 1)
3. *Chapter 3:* Analysis of existing AV-related measurement tools (adapted from Task 3)
4. *Chapter 4:* The AVEE Framework (adapted from Task 2)
5. *Chapter 5:* From the BUILD Grant project to Move Nona (adapted from Task 3)
6. *Chapter 6:* Move Nona project: baseline data and site analysis (adapted from Task 2)
7. *Chapter 7:* Move Nona survey development and analysis (adapted from Task 4)
8. *Chapter 8:* Move Nona's effectiveness scores
9. *Chapter 9:* Conclusion

Chapter 2. Literature Review of AV-Based Microtransit Programs

1. Overview

This literature review summarizes the primary AV or AV-based microtransit projects in the United States, Europe, Asia, and Australia, outlining essential characteristics such as the manufacturer, operator, business model, and ridership. Then, it investigates some quintessential AV shuttle programs in Europe, the United States, and Singapore, analyzing their performance outcomes, experiences gained, and passenger feedback. The literature review further examines challenges encountered and merits received by those projects during implementation to record the benefits and costs and ultimately identify room for improvement for future AV investors.

2. *Summary of Current AV-Based Microtransit Programs Worldwide*

Along with the surge of AV technology and market, multiple local and international companies, universities, city/regional governments, and transportation agencies have commenced testing/pilot programs of AV-based microtransit systems. The purpose is to verify the AV shuttle's reliability and market penetration potential as an alternative public transportation method. Simultaneously, the testing programs can attract users' and observers' perceptions of AV technologies and reveal complementary urban or transportation infrastructure needs (Mellano, 2020; WSP, 2021). **Figure 2-1** below are some most popular AV manufacturers and shuttle models in the world, with the main characteristics listed in Table 2-1.

Figure 2-1

Primary AV Shuttle Models

Note. The image of EZ10 is from *EZ10 passenger shuttle* [Photograph], by EasyMile, 2020, (https://easymile.com/vehicle-solutions/ez10-passenger-shuttle). The image of Apollong is from *Apollo* [Photograph], by Apollo, 2020, (https://developer.apollo.auto/index.html). The image of Arma is from *City* [photograph], by Navya, 2022, (https://www.navya.tech/en/usecases/city/). The image of Olli is from *Meet Olli 2.0* [Photograph], by K. Korosec, 2019, (https://techcrunch.com/2019/08/31/come-along-take-a-ride/).

Table 2-1

Key Characteristics of Primary AV Shuttle Models

Manufacturer[a]	Model	Country	Capacity[b]	Seat	Speed (mph)[c]
EasyMiles	EZ10	France	Up to 12	10	Up to 25
Navya	Arma	France	Up to 15	11	Up to 15.5
Apollo (Baidu)	Apolong	China	Up to 14	8	Up to 25
Local Motors[d]	Olli	US	Up to 12	8	Up to 25

Note. Data courtesy of EasyMile, Navya, Baidu, and Local Motors.

[a] The manufacturers design, build, and sell AV shuttles to service providers/operating companies worldwide. In other words, the buyers often purchase identical AV shuttle models and then apply customized paintings.

[b] A combination of seated and standing passengers.

[c] Passengers will increase the shuttle's weight and reduce its speed.

[d] Local Motors shut down in January 2022 due to a lack of demand and funding (Bellan, 2022).

1. North America

In North America, both the United States and Canada have implemented and tested AV-based microtransit projects (EasyMile, 2021; Local Motors, 2021; Navya, 2021). The service areas covered were:

1. *University campuses:* e.g., University of Michigan (Ann Arbor, MI) and University of Buffalo (Buffalo, NY)
2. *Transportation hubs:* e.g., Austin Airport (Austin, TX) and GoMentum Station (San Francisco, CA)
3. *Public roads: e*.g., Lake Nona (Orlando, FL) and the Montcalm Candiac (Montreal, ON)

As shown in **Table 2-2**, Navya's Arma, EasyMile's EZ10, and Local Motors's Olli have dominated the market, operated by local organizations and companies. Seven programs were on fixed routes ranging from 0.43 miles to 2.49 miles (0.7 to 4 km) and free, while some on-demand services with flexible routes required charges, e.g., the program at National Harbor, MD. The table further indicated that most service providers had only one or two AVs and were still at an early stage of development.

Table 2-2

Summary of Selected AV-Based Microtransit Services in North America

Location	Manufacturer	Operator	Launch	Vehicles	Length mi (km)	Fare	Road
University of Michigan, Ann Arbor, MI, US	Navya Arma	MCITY	12/2016	2	1 (1.6)	Free	Public road[1]
Lake Nona, Orlando, FL, US	Navya Arma	Beep	9/2019	2	2.2 (3.54)	Free	Public road
Las Vegas Blvd, Las Vegas, NV, US	Navya Arma	Keolis	11/2017	1	0.62 (1)	Free	Public road
Austin Airport, Austin, TX, US	EasyMile EZ10	AUS	8/2019	1	0.43 (0.7)	Free	Pedestrian area[2]
Virginia Tech, Blacksburg, VA, US	EasyMile EZ10	NRV	5/2019	1	0.5 (0.8)	Free	Public road
GoMentum Station, Concord, CA, US	Local Motors Olli	CCTA	10/2019	1	-[3]	-	Private property
National Harbor, MD, US	Local Motors Olli	MDOT	10/2019	1	-	Registration[4]	Public road
University of Buffalo, Buffalo, NY, US	Local Motors Olli	UB	9/2019	1	-	Free	Private property
Gainesville, FL, US	EasyMile EZ10	FDOT	1/2020	2	3 (4.8)	Free	Public road
The Goodyear Tire, Akron, OH, US	Local Motors Olli	Goodyear	2/2019	1	-	-	Private property
Montcalm Candiac, Montreal, Canada	Navya Arma	Keolis	8/2018	1	1.24 (2)	Free	Public road
Calgary Zoo, Calgary, Canada	EasyMile EZ10	PWT	9/2018	1	0.35 (0.557)	Free	Public road

Note. Data courtesy of *EasyMile, Local Motors,* and *Navya.*

[1] Public road: AV-based microtransit mixed with pedestrians, bikes, and motorized vehicles.

[2] Pedestrian area: AV-based microtransit mixed with pedestrians and bikes.

[3] "-" stands for "data not available."

[4] Free for registered members on https://rideolli.com/.

Note that the table did not enlist some completed pilot programs. For example, the famous Electric Driverless Demonstration in Yellowstone at Canyon Village, operated by Beep and the National Park Service, ended in August 2021 (Frank, 2022). Another Beep program that used AVs to deliver medical supplies and vaccines during the Covid-19 pandemic at Mayo Clinic in Jacksonville, FL, ended in July 2020 (Beep, 2021).

2. Europe

Two French companies, Navya and EasyMile, provide most AV shuttles for microtransit services in Austria, France, Germany, Italy, Luxembourg, the Netherlands, Norway, Sweden, and Switzerland (Actus Air, 2021; Avenue, 2021; EasyMile, 2021; Local Motors, 2021; Navya, 2021; PostBus, 2021; Wiener Linien, 2021).

As reflected in **Table 2-3**, 28 pilot programs took place from 2016 to 2020, and each program owned one to four AVs. Generally, operating the AVs relied on fixed routes, whose lengths ranged from 0.31 to 2.49 miles (0.5 to 4 km). This range was adequate for most urban areas, especially the older historical cities (rather than sprawling ones with massive suburbs commonly observed in the United States). On average, the service providers owned two AVs, with the largest fleet comprised of four. Almost all AV-based microtransit services were free to all passengers. It is worth mentioning that France piloted nine AV-based microtransit services, followed by Switzerland (five) and Germany (five).

Table 2-3

Summary of Selected AV-Based Microtransit Services in Europe

Location	Manufacturer	Operator	Launch	Vehicles	Length mi (km)	Fare	Road
Ilse-Arlt-Straße Wien, Austria	Navya Arma	Wiener Linien	6/2019	2	2.49 (4)	Free	Public road
Koppl Salzburg Research, Koppl, Austria	EasyMile EZ10	Digibus	4/2018	1	0.87 (1.4)	Free	Public road
University of Metropolia, Helsinki, Finland	Navya Arma	Metropolia	6/2019	2	1.24 (2)	Free	Public road
Confluence Lyon, France	Navya Arma	Keolis	9/2016	2	0.84 (1.35)	Free	Pedestrian area
Parc Olympique Lyonnais, France	Navya Arma	TCL Lyon	11/2019	2	0.87 (1.4)	Free	Public road
ZAC des Gaulnes Lyon, France	Navya Arma	Berthelet	3/2019	1	0.75 (1.2)	Free	Public road
l’Abbaye Fontevraud, France	Navya Arma	Keolis	5/2018	1	0.5 (0.8)	Free	Pedestrian area
Villejean, Universite de Rennes, France	Navya Arma	Keolis	1/2018	2	0.81 (1.3)	Free	Public road

First Fully Driverless Service Sorigny, France	EasyMile EZ10	TLD	11/2018	1	0.93 (1.5)	Free	Public road
Rue Paul Duez, Universite de Lille, France	Navya Arma	Keolis	12/2018	2	0.87 (1.4)	Free	Public road
Airport Velizy-Villacoublay, Paris, France	EasyMile EZ10	RATP/SCA	6/2018	1	-	Air Force[a]	Government property
Plateau de Satory Versailles, France	EasyMile EZ10	Transdev	12/2018	1	0.62 (1)	Free	Public road
Sylt Schleswig-Holstein, Germany	Navya Arma	SVG	5/2019	1	1.68 (2.7)	Free	Public road
InnoZ EUREF Campus, Berlin, Germany	EasyMile EZ10	BVG	12/2017	1	0.37 (0.6)	Free	Public road
Bad Birnbach, Germany	EasyMile EZ10	DB	10/2017	2	0.87 (1.4)	Free	Public road
Project See-Meile, Berlin, Germany	EasyMile EZ10	BVG	8/2019	1	0.75 (1.2)	Free	Public road
GreenTec Campus, Enge-Sande, Germany	EasyMile EZ10	BMVI	6/2018	1	1.68 (2.7)	Free	Public road
ITCILO Campus, Turin, Italy	Local Motors Olli	ITC ILO	1/2020	1	-	Registration	Public road
Contern, Luxembourg	Navya Arma	Sales Lentz	9/2018	1	0.62 (1)	Free	Public road
Goodyear, Colmar-Berg, Luxembourg	Local Motors Olli	Sales Lentz	3/2019	3	-	Free	Private property
Ommelander Hospital, Groningen, Netherlands	Navya Arma	Arriva (DB)	8/2018	1	0.62 (1)	Free	Public road
Oslo Waterfront, Oslo, Norway	Navya Arma	Holo	5/2019	4	1.24 (2.2)	Free	Public road
Lindholmen Science Park Gothenburg, Sweden	Navya Arma	Autonomous	4/2019	2	0.87 (1.4)	Free	Public road
Virginio-Malnati Meyrin, Geneve, Switzerland	Navya Arma	TPG Geneve	9/2018	2	1.3 (2.1)	Free	Public road
Place de la Planta Sion, Switzerland	Navya Arma	Car Postal	6/2016	2	2.2 (3.54)	Free	Public road
Neuhausen am Rheinfall, Switzerland	Navya Arma	VB/SH	3/2017	1	0.93 (1.5)	Free	Public road
l'Ancienne Marly, Fribourg, Switzerland	Navya Arma	TPF	8/2017	2	0.81 (1.3)	-	Public road
Bernmobil Demo, Bern, Switzerland	EasyMile EZ10	AVOC	6/2019	1	1.24 (2)	Free	Public road

Note. Data courtesy Actus Air, EasyMile, Local Motors, Navya, PostBus, and Wiener Linien.

[a] Only available for Air Force-permitted users.

3. Asia and Australia

As shown in **Table 2-4**, China launched nine pilot programs between 2017 and 2019 to test or demonstrate AV-based microtransit services in different metropolitans or regional urban centers, including Beijing, Xiamen, Shenzhen, Wuhan, Nanjing, Hong Kong, and Yangquan (Apollo, 2021; EasyMile, 2021; Navya, 2021).

Most microtransit services were developed and provided by Baidu Apollo (the third model from the left in **Figure 2-1**), with the exception of Southeast University (EasyMile's EZ10) and Hong Kong (Navya's Arma). Baidu's minibus, Apolong, could seat up to 14 people. Since 2017, Apolong has become the only AV minibus under mass production other than Arma, Olli, and EZ10 (Korosec, 2018).

Some pilot programs in China were advanced, with more AVs and longer route lengths than those in North America and Europe, particularly in Yangquan (22 vehicles and 16.1 miles/26 km) and Wuhan (10 vehicles and 3.1 miles/5 km). Furthermore, these services were all free and available to registered passengers.

Table 2-4

Summary of Selected AV-Based Microtransit Services in Asia and Australia

Location	Manufacturer	Operator	Launch	Vehicles	Length mi (km)	Fare	Road
Southeast University, Nanjing, China	EasyMile EZ10	NJNDTIG	10/2018	1	0.87 (1.4)	Free	Public road
Software Park, Xiamen, China	Baidu Apollo	Baidu	4/2018	1	-	Free	Public road
Kink Long, Xiamen, China	Baidu Apollo	Baidu	3/2018	1	-	Free	Pedestrian area
Haidian Park, Xiamen, China	Baidu Apollo	Baidu	5/2019	1	-	Registration	Pedestrian area
Xiongan New Area, China	Baidu Apollo	Baidu	12/2017	5	2.49 (4)	Free	Public road
Shenzhen, China	Baidu Apollo	Shenzhen Bus	12/2017	4	0.75 (1.2)	Free	Public road
Yangquan, Shanxi, China	Baidu Apollo	Baidu	1/2019	22	16.2 (26)	Free	Public road

Wuhan, China	Baidu Apollo	Baidu	10/2018	10	3.1 (5)	Free	Pedestrian road
Nursery Park, West Kowloon, Hongkong	Navya Arma	West Kowloon	7/2017	1	0.19 (0.3)	Free	Pedestrian area
King Abdullah University, Thuwal, Saudi Arabia	Local Motors Olli	SAPTCO	12/2019	3	-	Free	Public road
National University of Singapore, Singapore	EasyMile EZ10	Comfort DelGro	7/2019	1	1 (1.6)	Free	Public road
Masdar City, Abu Dhabi, United Arab Emirates	Navya Arma	Navya	9/2018	3	0.56 (0.9)	Free	Pedestrian area
St Perth Esplanade Perth, Australia	Navya Arma	RAC	7/2016	2	2.17 (3.5)	-	Public road
Flinders University Adelaide, Australia	Navya Arma	Flinders	6/2018	1	0.75 (1.2)	Free	Public road
Renmark Aged Care, Renmark, Australia	EasyMile EZ10	TAG	8/2019	1	2.8 (4.5)	Free	Public road
BusBot, Toormina, New South Wales, Australia	EasyMile EZ10	Busways	6/2019	1	0.62 (1)	Free	Pedestrian area

Note. Data courtesy of Apollo, EasyMile, Local Motors, and Navya.

In other Asian countries, Singapore launched a pilot project in 2019, operating the EasyMile EZ10 at the National University of Singapore (EasyMile, 2021). The project had one autonomous vehicle serving passengers on a one-mile (1.6-km) fixed route. Singapore aimed to build experiences and deploy various AVs, such as road-sweepers, freight carriers, and on-demand shuttles for after hours and at night, to ease congestion and labor cost (Ng, 2020). In the Middle East, Local Motors's Olli and Navya's Arma facilitated AV-based microtransit services in Saudi Arabia and the United Arab Emirates in 2019 and 2018, respectively (Local Motors, 2021; Navya, 2021). These two pilot programs deployed three AVs each in a university and a new, master-planned community, and the services were also free for passengers.

Australia launched four pilot programs to implement AV-based microtransit services in the last few years (EasyMile, 2021; Navya, 2021). The first two programs used Navya's Arma, equipped with two and one AVs each, and operated on 2.2-mile (3.5 km) and 0.75-mile (1.2-km) routes, respectively. The two other programs, started in 2019, used EasyMile's EZ10 vehicles and ran on 2.8-mile (4.5-km) and 0.62-mile (1-km) fixed routes. Passengers in the St. Perth Esplanade (Perth, Australia) had to pay for the AV-based microtransit services.

3. Review of Selected Implemented Projects

Applying AV-based microtransit services has become a global trend, but the effects and long-term outcomes could vary greatly depending on their geographical regions. Therefore, analyzing and providing an overview of some selected AV-based microtransit services' outcomes and people's attitudes was crucial. Selected programs contained three from Europe, one from the United States, and one from Singapore.

1. The Success of AV Shuttle Pilot Programs in Europe

As presented in the previous section and in **Table 2-3**, European countries developed and launched nearly one-half of the currently operating AV-based microtransit pilot programs globally. These AV-based microtransit services generally exhibited the following characteristics:

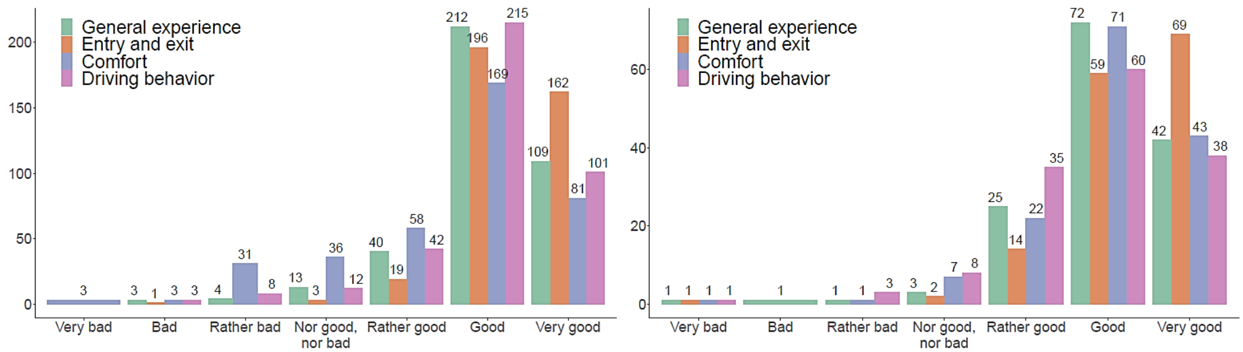
1. About 0.93 miles (1.5 km) of fixed routes
2. Between 5 and 6 designated stops
3. A low speed between 6.2 and 9.3 mph (10 to 15 km/h)
4. A capacity of 8–12 passengers.
5. Mostly ride with no charges (free)

In addition, some operators' survey reports demonstrated that AVs could become a potential solution for first- and last-mile trips from transit stations. Meanwhile, people with a habit of traveling by train were more likely to use shared AVs. Moreover, AV users tended to be younger people with higher curiosity and less concern about the safety or security onboard (Avenue, 2020; Azad et al., 2019; Wiener Linien, 2021).

Feys, Rombaut, and Vanhaverbeke's 2020 article studied two AV-based transit pilot programs in Brussels Capital Region, Belgium, which uses EZ10 shuttles manufactured by EasyMile. For the first program, two AV shuttles operated on a 0.9-mile fixed route with five station-based stops in the municipality of Sint-Pieters-Woluwe. The second program used AV shuttles to connect student dormitories to the auditoriums of the Brussels Health Campus in the municipality of Jette. Field surveys and data showed that 5,293 passengers rode the AV-based microtransit service. More than 70 percent of the passengers expressed no safety concerns about using AV. Furthermore, passengers reported a positive experience with the AV-based microtransit service and evaluated the service positively for comfort of the vehicle, ease of getting in and out of the vehicle, the driving behavior of the vehicle, and the general user experience (see **Figure 2-2**).

Figure 2-2

Selected AV Survey Results in Belgium



Note. Comparing survey respondents' opinions on four aspects of AVs. Woluwe Park program (left). Brussels Health Campus program (right). From *Feys, Rombaut, and Vanhaverbeke* (2020).

Germany's Project See-Meile was another example. This test of AV-based microtransit service had six phases, used EasyMile shuttles with a capacity of eight to 12 passengers, and operated on two fixed routes at a speed of 6.2 to 9.3 mph. EasyMile's (2021) report on the deployment pointed to positive relationships between the quality of the service and passengers' intention to use them. Additionally, respondents were generally favorable toward most aspects of the AV shuttles, e.g., comfort, design, and ease of boarding, but were less satisfied with its speed.

2. Beep's Demonstration in Yellowstone

The Electric Driverless Demonstration in Yellowstone (TEDDY), deployed by the National Park Service and operated by Beep, was a 100-day pilot AV shuttle project showcasing two routes designed to connect visitors to popular destinations, such as the visitor centers, eateries, lodges, and campgrounds (Beep, 2021, 2022). A highlight of the project was that it successfully carried about 10,000 tourists and eliminated roughly 5,600 vehicle trips, which testified to the AV shuttle's capability to meet transportation demands even during peak summer months. Another highlight was that Beep proved its management ability by keeping a perfect operation safety record while monitoring, supporting, and mitigating risk from a remote command center. Takeaways from TEDDY include that the existing AV shuttle models (e.g., Olli and Arma) could work for long hours and would automatically avoid incidents like wildlife intrusion.

3. The Autonomous Bus Projects in Singapore

The Nanyang Technological University (NTU), in Singapore, launched the world's first full-size autonomous electric bus, Volvo 7900, in 2019 (**Figure 2-3**). In contrast to the smaller, more commonly seen autonomous vans, which could carry up to 15 people, the 40-feet (12-meter) bus could carry 80. The new bus started its testing program at NTU's Smart Campus, signifying an attempt to create an alternative method of transferring larger groups (Wei, 2019). Two years later, Singapore started another autonomous bus service with a three-month trial around the city-state's Science Park (Yong, 2022). One takeaway of Singapore's efforts was that AV buses might be suitable for transporting people to and from crowded places, like airports. Many regions in the United States, however, might need smaller AVs due to their low density.

Figure 2-3

The Volvo 7900 Autonomous Electric Bus in NTU

Note. From *World's first full size autonomous electric bus* [Digital Image], by Volvo Buses, 2019, (https://www.volvobuses.com/en/news/2019/mar/volvo-and-singapore-university-ntu-unveil-world-first-full-size-autonomous-electric-bus.html).

4. Review of Implementation Issues

1. Safety Concerns

Challenges and opportunities always coexist when adopting new technology. When implementing AV-based microtransit services, which would significantly alter the future transportation system and influence people's travel patterns, safety is the primary concern of all.

On the one hand, Litman (2021) and Coletti (2021) pointed out that some optimists might believe that autonomous vehicles would be a silver bullet in reducing car and bus crash rates because human errors such as distracted driving, fatigue, and driving under the influence are significant contributors to traffic crashes. On the other hand, skeptics stressed that AV's real-world crash-avoidance systems were still immature and under development, and that mitigating crashes required additional elements like good roadway design. Besides, people should not overlook additional risks introduced by AV technology, which people rarely experienced previously. Some of those novel issues were technical, and others involved social and behavioral factors, presented by the following examples (Consumer Reports, 2014; Litman, 2021):

1. **System failures:** software errors and hardware failures, e.g., broken sensors and unstable wireless connectivity, are inevitable on electronic systems, causing unpredictable crashes.
2. **Malicious hacking:** AVs could be misused and disrupted by cyberattacks. Hackers might manipulate self-driving technologies or damage the control system for crime.
3. **Over-trusting:** people might over-trust the AV system, assuming it would always be safe and brake in time, thus becoming careless, e.g., releasing safety belts.
4. **Risks of road sharing:** other travelers who share the road with an AV but are not familiar with it, including drivers, pedestrians, and cyclists, might be confused and face risks. During inclement weather, it would be hard for AVs to detect and accommodate all surrounding objects.
5. **Maintenance difficulty:** additional high-tech elements and delicate facilities, e.g., lidars and radars, are more complicated and expensive to operate, repair, and maintain than traditional vehicles, requiring more specialized technicians.
6. **Programming failures:** programmers might provide wrong information, e.g., maps with mistakes or no backup plans to cope with unexpected situations and bugs.

2. Urban Infrastructure

The development of AV-based transit systems often faces substantial uncertainties in complex urban traffic. For AVs to operate reliably, improving urban infrastructure is as essential as enhancing AV technologies. AVs vehicles require far more infrastructure than existing roads and facilities in most of our cities.

Canis (2021) stated that AVs would need new infrastructure support and maintenance types, including "advanced telecommunications links and near-perfect pavement and signage markings." For instance, future "smart" roads should contain multiple roadside sensors on lanes, curbs, and sidewalks to capture and convey instant traffic conditions, allowing AVs to foresee risks and respond far ahead. Machine-readable signs and radar-reflective road markings are two other critical elements that could replace today's sophisticated image-recognition approach with reading AV-detectable codes embedded in signs or lanes for better accuracy (Haydin, 2019). In addition, since most test AVs were electronic vehicles, building more refueling or charging stations would be another concern (Canis, 2021). Almost a century of car-oriented development has contributed to the prevalence of gas stations. The efficiency and easiness of gasoline refueling are still unparalleled.

However, the United States is not leading the race of planning and building urban infrastructure for an era of AV. According to the Autonomous Vehicle Readiness Index (AVRI) by KPMG International (2020), which ranked the most AV-ready countries, the United States' infrastructure pillar score was only in ninth place. **Table 2-5** indicates the pillar's six measures and compares each score between the United States and the Netherlands. The Netherlands has received the top overall score after spending over €90 million (around $103 million USD) in 2020 to upgrade around 1,000 traffic lights that could communicate with AVs. Roughly 107,000 public and private electric vehicle charging stations are situated along regularly maintained roads and freeways, leading to the world's highest charging point accessibility (KPMG, 2020). In contrast, the United States' electric vehicle charging point accessibility score was much lower, implying a high reliance on traditional gas stations. Also, only 41 percent of roads in the United States met the requirements for a "good ride," impairing the deployment of AV transit services and requiring amelioration and renovation (Duvall et al., 2019).

Table 2-5

AV Infrastructure Pillar Score and Measure Scores

	Measure	The Netherlands	United States
1	EV charging stations	1.000	0.070
2	4G coverage	0.832	0.839
3	Quality of roads	0.993	0.714
4	Technology infrastructure change readiness	0.622	0.600
5	Mobile connection speed (half weight)	0.755	0.393
6	Broadband (half weight)	0.792	0.917
	Overall pillar score (rank)	**4.221 (1)**	**2.878 (9)**

Note. Data is from the *2020 AVRI report*, by KPMG International, 2020.

3. Funding

Duvall et al. (2019) outlined the serious funding and financial challenges of developing more AV-based microtransit services in the United States. The expansion of AVs and electric vehicles (EVs) would burden the budget deficits of the Federal, State, and Local governments, especially the severely under-resourced transportation branch. The backlog of transportation infrastructure needs in 2019 was approximately $836 billion USD and repairing the existing roads and upgrading them to be "smarter" enough to accommodate more AVs could exacerbate the current gap by 22 percent – about $80 billion USD – by 2040.

Deployment of an AV-based microtransit system might lead to other financial issues. First, since most AVs will be electric, revenues gathered from fuel and emissions taxes would fall significantly, causing immediate problems to all levels of government and impacting all public sectors simultaneously. Second, as more people start driving AVs or taking AV shuttles, the demand for private cars would also decrease, leading to a plummeting of multiple fees, such as car registrations, smog tests, and driver's license application fees (Duvall et al., 2019). Additionally, AVs would impact the local and national job market without the need for drivers. Reinicke (2018) estimated that AVs could eliminate 300,000 driving jobs a year, making the 15.5 million workers whose jobs are related to driving, like truck and taxi drivers, vulnerable. Therefore, choosing a sustainable and suitable business model is paramount. Determining whether a city should fully fund a pilot project, obtain research grants, or fund through public-private partnerships requires more meticulous investigation.

4. Social Acceptance

Despite the apparent benefits, such as crash reduction, traffic flow enhancement, and mobility improvement, convincing consumers to accept AVs in their daily lives by building individual trust remains challenging and complicated (Adnan et al., 2018; Koopman & Wagner, 2017).

Koopman and Wagner (2017) indicated that the primary incentive for replacing human drivers with an AV system was an expectation that AVs would be safer and more reliable than people. However, this assumption relies on zero mishaps and is unrealistic. Any potential accidents would undermine the public's confidence in this technology. For example, "a falling tree hitting a car in a storm" could make the expectation of avoiding a collision physically impossible.

Choe et al. (2015) conducted a questionnaire survey and a focus group interview, targeting people with driver's licenses to identify the factor that might affect their trust in AVs and analyzing their requirements to accept driving in an AV environment. The result showed that competency and error management were vital factors influencing trust, with focus group participants responding that they were still doubtful about the safety of AVs at their current stage and needed all driving information before using such vehicles.

Lee et al. (2018) worked on a similar study that focused on the main factors of AVs that would affect consumers. The study found that usefulness, reliability, and legality were the top three factors influencing people's acceptance. Therefore, emphasizing convenience and safety are essential when developing and promoting AVs.

What is more, Koopman and Wagner (2017) stressed that the world had yet to reach a mutual agreement on AV safety standards. It was still controversial whether the standard should be "better than an excellent human driver, or merely a typical human driver," with even the definitions of "excellent" and "typical" still in question. Such uncertainty would exacerbate people's dubitation.

5. *Takeaways*

The literature review has identified the following research gaps to be addressed by this research:

First, almost all existing AV-based microtransit services were pilot/demonstration programs. They shared several similar features, including a short implementation period (about two years), limited numbers of AVs (usually one/two vehicles), reliance on fixed routes in urban areas, and low speed (less than 15 mph). These findings implied that the AV-based microtransit projects were still experimental and needed more time to examine their profound influences to determine if they could replace existing mass transit systems, especially with longer distances, in the future.

Second, regarding the impact and effectiveness of the AV-based microtransit system, most data were primary data like consumer feedback. These answers might be biased since the operator collected them directly. This problem signified the importance of drafting an interview with a complete set of questions managed by a third party to improve accuracy and ensure impartiality.

Third, the case studies in Europe serve as a reminder that young people prone to novelty became the dominant group of riders. This indicates the significance of studying how passengers' motivations inform riding behavior with AVs. Studying this subject can help providers to better fulfill rider needs while discovering strategies to attract users from other age groups.

Fourth, current literature or studies lacked systematic and well-accepted performance measures with detailed criteria to evaluate the outcome of project implementation. Without such measures to quantify the effectiveness of these new services, finding pros and cons, revising business plans, fixing problems, and applying for further investments would be challenging. Meanwhile, the KPMG's AV readiness report could offer suitable lessons on setting ranking pillars, although it focused on the national rather than local level.

Fifth, among all the issues, safety and funding were two priorities. The former was still the primary concern that affected public acceptance. The latter left decision-makers with an intriguing question of how to choose the correct business model to finance an AV-based microtransit service.

Chapter 3. Analysis of Existing AV-Related Measurement Tools

1. Overview

In Chapter 2's review of the existing AV-based microtransit systems, we established that almost all projects were in testing or pilot phases with short implementation periods. We also found that most existing AV performance/effectiveness data consisted mainly of customer surveys that were not based on a commonly accepted methodology. Additionally, the predominant user group of these AV systems was younger individuals who were more receptive to innovative technology and novel modes of travel. The results of this industry snapshot further supported our initial postulate that the current research or study lacked an accepted and comprehensive performance evaluation framework applicable to similar AV projects.

By building upon observations and conclusions presented above, this chapter continued to explore and analyze some of the most professional, widely accepted tools or rating systems for measuring the effectiveness, success, or readiness of AV systems or other urban projects in related fields, including public transportation and sustainable development. The primary rating systems listed below inspired and assisted us in designing the evaluation framework for AV-based microtransit programs. We adopted one or multiple features, such as the measuring criteria and scoring scales, from the following systems:

1. Florida's Connected and Automated Vehicles Business Plan, by FDOT
2. 2020, 2019, and 2018 Autonomous Vehicles Readiness Index (AVRI), by KPMG
3. The Sustainable Development Goals (SDG) Impact Assessment Tool, by UN Habitat
4. Connected and Autonomous Vehicles 2040 Vision Report, by PennDOT
5. Measuring Scheduled Bus Service Quality, by Prioni & Hensher (2000)
6. Technology Acceptance Model (TAM), by Davis
7. Measuring the Completeness of Complete Streets Study, by Hui et al.

From a broader perspective, leveraging the existing literature's useful features and eliminating the inapplicable ones helped us to "stand on the shoulders of giants" and make significant intellectual progress. From a smaller scope, adopting criteria and elements from recognized evaluation tools could justify the soundness and convincing power of the new framework.

2. Summary of Related Rating Systems

1. The Florida's CAV Business Plan

FDOT (2019) has initiated the Connected and Automated Vehicles (CAV) Business Plan, initiating several CAV pilot projects in recent years to pursue sustainable safety, mobility, and economic development benefits in Florida (SME). Published in 2019, the CAV Business Plan identified specific CAV short- to long-term action items, facilitating the development of an institutionalized framework to actively move CAV programs from research phases to statewide deployment. The plan provided project selection criteria and performance measures to guide potential CAV projects seeking funding or deployment, shown in **Table 3-1** below.

Table 3-1

Project Selection Criteria and Scoring Matrix of the CAV Plan

Categories	Criteria
Accelerate the CAV program	Does this project accelerate the deployment and implementation of CAV technologies in Florida?
Safety	Does this project directly reduce or have the potential to reduce fatal, serious injury and/or secondary crashes?
Mobility	From a mobility perspective, does this project directly benefit all modes including pedestrians, bicyclists, disabled, economically disadvantaged, and aging road users?
Efficiency and reliability	Does this project directly benefit (or have potential to impact) efficiency and/or reliability for all travelers, freight, transit riders, aging road users, pedestrians, and bicyclists?
feasibility	Is this project implementable (technology-ready), scalable, and portable for statewide deployment?
	Do proposed technologies comply with or have the potential to comply with relevant state and federal safety law?
	Is the proposed project interoperable and/or does it have the potential to become interoperable with the existing/programmed CAV Projects?
Funds	Does this project leverage federal, local, and/or private funds? Are there any private organization and/or local agency partners? If yes, what are their match types and roles? Is there an agreement or Memorandum of Understanding in place?
Benefit/cost	Does this project offer benefits with a high B/C and a good return on investment?
Data and security	Does this project collect, disseminate, and use real-time traffic, transit, parking, and other transportation information to improve safety and mobility, and reduce congestion? Explain how the project will safeguard data privacy and deploy a cybersecurity platform.

Operations and maintenance	Does this project address staffing, funding, and procedures for operations, maintenance, and replacement of CAV infrastructure, technologies, and applications?
Project evaluation	Does this project have pre-defined performance measures? What and how are these outcomes measured?
	Will there be a before and after analysis performed, and lessons learned documented? If yes, how will this be documented and shared?
	Is there a systems validation and verification process in place? Explain how this will be performed.

Note. Adapted from Table 9 of the *Florida's Connected and Automated Vehicles (CAV) Business Plan,* by FDOT, 2019.

According to FDOT (2019), the central office and users could answer the questions in **Table 3-1** and then assign a score by themselves on a scale of one to 10 (10 being the most beneficial rank) for each criterion of a selected project to determine whether to prioritize it in the district.

The advantage of this ranking system is that it comes from an official FDOT plan, setting a benchmark for all similar project evaluation processes in Florida. In other words, new frameworks, like assessing the BUILD Grant project, could stem from it. Also, this system clarified the ultimate standard of an AV project's effectiveness: whether it could achieve SME benefits or not, which firmly navigated the direction and purpose of adding more detailed and customized measuring criteria. Additionally, the CAV plan's framework has covered several critical criteria for assessing AV projects, such as safety, funding, return on investment, and feasibility, which our new framework should consider adopting.

On the other hand, this framework still had many shortcomings, in that it is a relatively simple and over-generalized rating system. Most importantly, it was a rating system for project selection instead of evaluation, which disallowed us from directly using it to assess the BUILD Grant project or Move Nona AV shuttle system. Also, the scoring system relied on 10 subjective questions, causing two severe issues: first, the comprehensiveness of the criteria was doubtful. Many questions were too broad and sometimes vague. For example, the "mobility" and "efficiency" criteria did not cover many details, such as how to assess indicators like travel speed, riding frequency, and accessibility to the stops. Another example was that users could not find a method to calculate benefits and costs or return on investment, since many AV projects were free. The “safety” criterion only focused on crashes or injuries but neglected people’s safety concerns about new technology per se. The second issue was that the rating/scoring was subjective: there is a need to encompass more objective measures, e.g., infrastructure quality of the AVs and the roads, enforcement of government and legal support, and service coverage.

Therefore, to develop our evaluation framework, we can use the CAV plan’s selection criteria as a foundation and keep both its objective of pursuing SME benefits and the concept of its scoring matrix. Meanwhile, we need to modify and tailor it in line with assessing AV-based microtransit projects’ effectiveness rather than a general AV service by adding more customized criteria or pillars and sub-criteria/elements. Moreover, criteria like infrastructure quality and ridership impacts need more objective scoring systems, while the rest (e.g., residents’ acceptance) should rely on community survey results to make the new framework more convincing and explicit.

2. The Autonomous Vehicle Readiness Index

KPMG (2020) published its first Autonomous Vehicle Readiness Index (AVRI) in 2018, a tool to evaluate 30 countries’ AV readiness levels. In its most recent 2020 version, this composite index combined 28 individual measures from varied sources into four pillars (**Table 3-2**). KMPG marked the scores using publicly available reports and press releases. Specifically, the first step was to get individual scores of each variable and combine them to arrive at an aggregate score for each pillar, where variables had equal weight (except the “mobile connection speed” and “broadband,” which had half the weight). Then they applied the min-max method to normalize all variables into the same scale from a score of zero to one for ranking and comparison.

Table 3-2

Pillars and Measures of the AVRI 2020

Pillar	Measure
Policy and Legislation	AV regulations Government-funded AV pilots AV focused agency. Government readiness for change. Future orientation of government Efficiency of the legal system in challenging regulations Data-sharing environment

Technology and Innovation	Industry and Partnerships AV technology firm headquarters AV related patents Industry investments in AV Availability of the latest technologies Innovation capability Cybersecurity Assessment of cloud computing, AI, and IoT Market share of electric cars
Infrastructure	EV charging stations 4G coverage Quality of roads Technology infrastructure change readiness Mobile connection speed Broadband
Consumer Acceptance	Population living near test areas Civil society technology use Consumer ICT adoption Consumer digital skills Individual readiness Online ride-hailing market penetration

Note. Adapted from the *2020 AVRI report*, by KPMG International, 2020.

However, the AVRI was not a tool to measure a single AV-based microtransit project and had two major limitations:

1. AVRI could only assess readiness, i.e., the preparedness level for embracing AV technology, and could not be used as a post-deployment evaluation tool.
2. AVRI's study targets/objectives were nations rather than projects on a neighborhood scale. Thus, many of its measures and variables, such as the "market share of electric cars" and "AV technology firm headquarters," could not apply to a project-based evaluation.

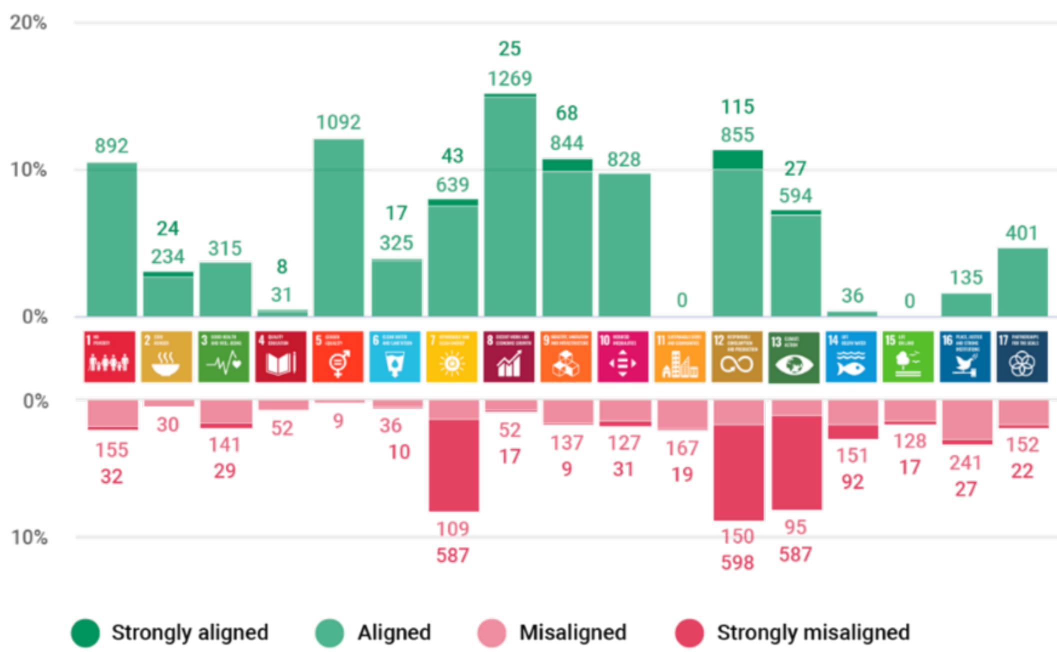
Albeit not directly replicable to a project-based assessment framework, the AVRI has offered two valuable takeaways. The first was the "pillar to variable" scoring system with different focusing areas of equal weight, which would work perfectly with our AVEE Framework. The other takeaway was to adopt the titles and part of the contents of the four pillars, especially Pillars 1 and 2, which were vital for evaluating an AV project in a neighborhood. Two possible modifications were: first, to use a unified scoring scale, e.g., a zero-to-five scale, to eradicate confusion; and second, to customize the variables to match our scenario.

3. The UN-Habitat Sustainable Development Goals Tool

The UN-Habitat's Sustainable Development Goals (SDG) Impact Assessment Tool assesses how well an urban project fits the UN's SDG goals, e.g., SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action). It uses a top-down "pillar, criteria, and sub-criteria" system (similar to AVRI's), except it adopts a three-point scoring scale. UN-Habitat created over 200 sub-criteria for the tool, covering all SDGs. Stakeholders, government officials, and urban planners from UN-Habitat hold workshops to rate a project based on the scoring scale, accumulating criteria scores into pillar scores to quantify the project's alignment with UN SDGs (see **Figure 3-1**). Besides the workshop rating strategy, another takeaway from the UN SDG tool is to customize the SDG tool to target distinct projects in line with customer needs. Not all criteria are appropriate or closely related to a project; using every element will be time-consuming. For instance, when measuring a public transportation project, one could remove irrelevant criteria like SDG 2 (Zero Hunger) to simplify the framework.

Figure 3-1

An Example Result from the UN SDG Tool



Note. The above is a hypothetical assessment of various companies' UN SDG alignments. From *Assessing Company Alignment with UN SDG,* by O., Emelianova, 2020, (https://www.msci.com/www/blog-posts/assessing-company-alignment/02085389620)

4. Additional Evaluation Frameworks

The resources listed below have also set intellectual foundations, provided scientific evidence, or offered ideas for ways to visually represent our evaluation framework:

1. **CAV 2040 Vision Report,** by PennDOT. This report has enriched our choices of AV evaluation criteria, especially measuring safety, transportation facility qualities, and road conditions.
2. **Technology Acceptance Model,** by Davis. The Technology Acceptance Model was a classic model to test people's acceptance of new technology by asking preference statement questions on ease of use and usefulness. The system inspired us to build survey questions to gather data on community and passengers' opinions regarding AV shuttles.
3. **Measuring the Completeness of Complete Streets Study,** by Hui et al. (2018). This paper offered a rating scale for assessing the completeness of streets for AVs, emphasizing street infrastructures and signages.
4. **Measuring Service Quality in Scheduled Bus Services,** by Prioni and Hensher (2000). The article presented a classic framework with a set of indicators (see **Table 3-3** for examples) to represent a user-based measure of bus service quality.
5. **City Resilience Index,** by ARUP (2015). The index could provide a comprehensive and technically robust basis for measuring city resilience, using 156 questions to assess 52 resilience indicators. It also visualized the result by a donut/sunburst chart.

Table 3-3

A Selected Set of Attributes in Measuring Bus Service Quality

Attribute	Answer choices
Walking distance to the bus stop (in minutes)	1. Same as current 2. 5 minutes farther 3. 10 minutes farther
Travel time	1. 25% faster than the current travel time 2. Same as current 3. 25% slower than the current travel time
Safety on board	1. The ride is very smooth 2. The ride is generally smooth, with rare sudden braking 3. The ride is jerky; sudden braking occurs often

Note. From *Measuring Service Quality in Scheduled Bus Services,* by P. Prioni and D. Hensher, 2000, *Journal of Public Transportation, 3(2),* p. 54. (DOI:10.5038/2375-0901.3.2.4).

Chapter 4. The AVEE Framework

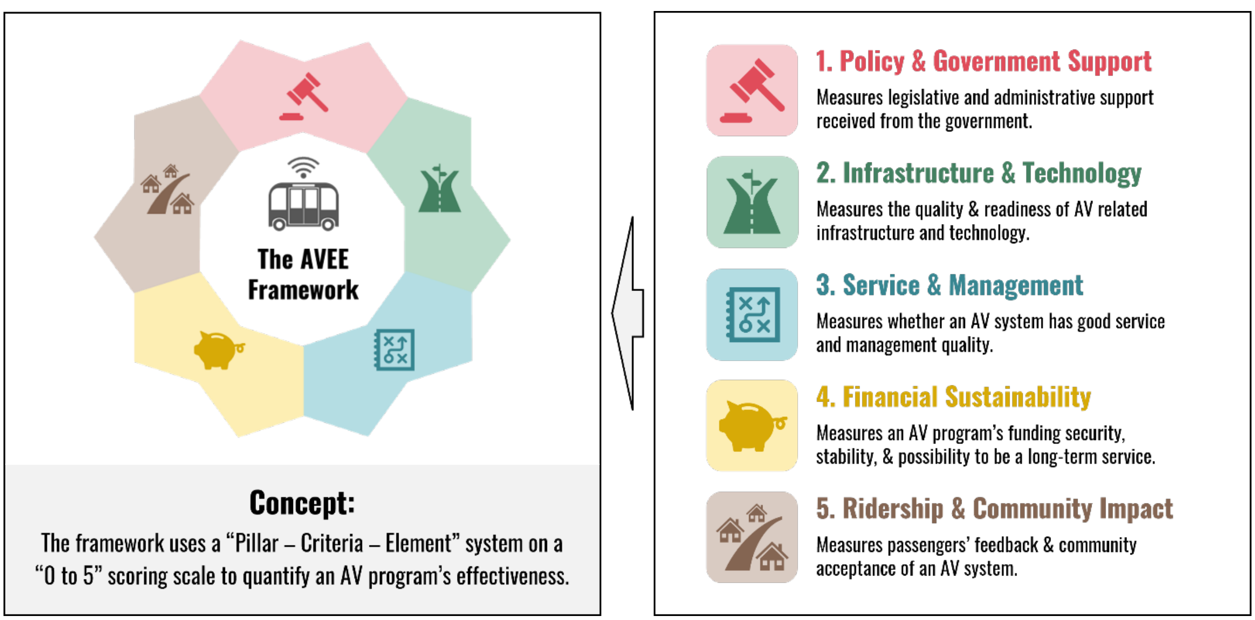
1. Overview

The AV-Based Microtransit Effectiveness Evaluation Framework (referenced as the "**AVEE Framework**") developed within this study is envisioned as a comprehensive, user-friendly instrument to better inform and equip decision-makers statewide and nationwide on the rapidly advancing AV-based microtransit industry and market. By providing the criteria for ranking available options, the AVEE Framework will allow purchasers or managers to quantify potential AV systems' political, economic, technical, and social implications and the actual impacts of similar existing AV systems conveniently and scientifically.

The AVEE Framework (see **Figure 4-1**) comprises five pillars, supported by 10 primary criteria and 35 elements (sub-criteria) derived from existing literature and already implemented AV transit system cases worldwide. Framework users can obtain, aggregate, and normalize scores of each element into criteria and pillar scores, representing an AV system's effectiveness. Later sections of this chapter will expound on the framework's details and provide a user guide.

Figure 4-1

Conceptual Diagram of the AVEE Framework



Note. The diagram of the AVEE Framework. Own work.

2. The Objectives, Roles, and Users of the AVEE Framework

Fast-growing interests and concerns surrounding autonomous transit's feasibility, effectiveness, and utility have presented many public and private transportation professionals with immense ambiguities when making multifaceted and expensive investment decisions. For instance, in one possible scenario of determining which AV product to implement for a neighborhood, it would be challenging for the authorities to select the most excellent one from multiple offers and bids. Also, it would be tough for them to assess and quantify the performane of the selected program during the implementation phase to make revisions or, at the ending phase, to summarize outcomes. Therefore, the AVEE Framework, tailored to meet the decision-makers' needs, confronts the selection of an adequate AV-based transit system by asking whether an investment in such a system would fully meet the requirements of their constituents or customers.

Below are the three main objectives of the AVEE Framework:

1. Allow potential purchasers and city authorities or managers to have a practical tool to quantify an AV system's political, economic, technical, and social implications.
2. Navigate a collaborative and participatory process among professionals and stakeholders seeking to determine the viability and possible gains and losses of implementing an AV system in a neighborhood, city, or region.
3. Create an enabling environment to explore and optimize potential AV-based microtransit strategies that align with stakeholder objectives and demands.

The roles of the AVEE Framework are as follows:

1. As a **project evaluation tool**, the AVEE Framework can be used for:
   - project context assessment
   - effectiveness and impact assessment
   - feasibility, in-progress evaluation, and final evaluation
2. Aa a **project enhancement tool**, the AVEE Framework can be used for:
   - project quality improvement
   - future project development
   - steering participatory process

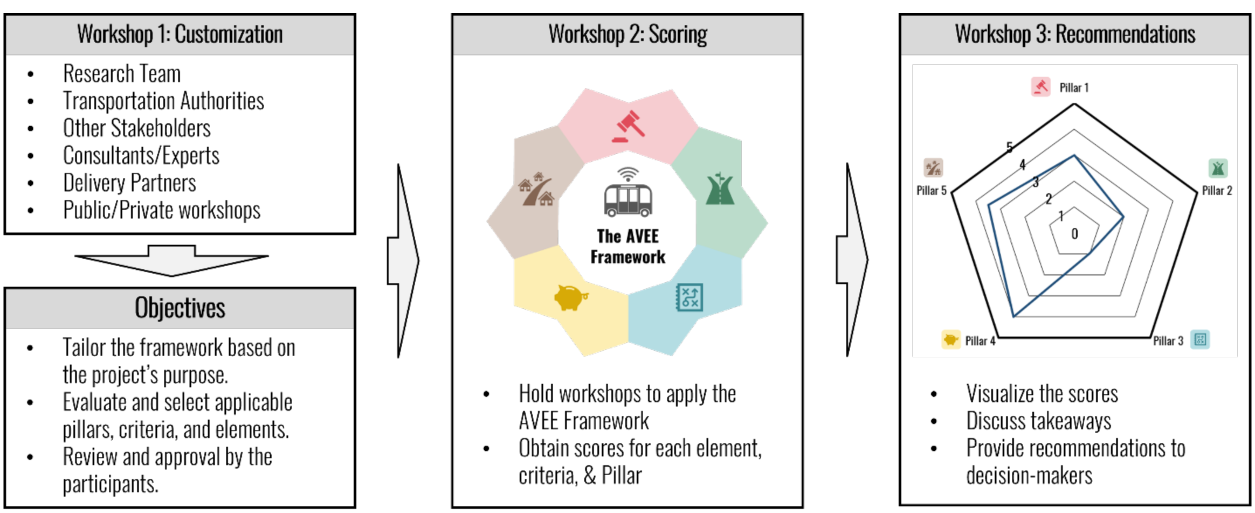
Additional examples and descriptions of the AVEE Framework's target users and potential value-adds include:

1. **Local or regional authorities, municipalities, and transportation departments:** The tool provides these public transportation professionals and other authorities with quantified criteria to assist in developing scopes of work, requests for proposals, vendor selection and ranking, measurements of effectiveness, transportation development plans, and grant funding selection.
2. **Business owners:** Private companies can utilize this tool to inform strategic investment plans, develop project proposals, quality-check internal processes and parameters, and assist in identifying opportunities and threats related to AV business competition and project planning. Additionally, private AV transit system providers/vendors can use this tool to better understand their customers' needs, potential impacts of their product, and lessons learned from past implementations.
3. **Researchers and educational institutions:** Students and academic professionals can use the tool to inform future research efforts, identify new research opportunities, benchmark industry components, and provide additional insight and analysis.

Figure 4-2 below is a visual user guide for applying the AVEE Framework.

Figure 4-2

User Guide: The Process of Applying the AVEE Framework



3. Pillar 1: Policy and Government Support

1. Content, Scoring Metrics, and Explanations

The Policy and Government Support Pillar (Pillar 1) has two performance-measuring criteria:

1. government legislative support of the AV-based microtransit system
2. government administrative support of the AV-based microtransit system

In short, Pillar 1 (**Table 4-1**) measures the readiness and suitability of a city/state to implement an AV system. This pillar is vital because successfully launching a new public transportation system is contingent on solid promotion and endorsement from state and local governments. These entities are responsible for passing relevant laws, regulations, and plans, resolving complex legal matters, managing financial resources, attracting investment, and enhancing existing infrastructure to fully and timely meet users' needs.

Table 4-1

Pillar 1: Policy and Government Support

Criterion 1.1: Legislative support for AV-based microtransit systems	
Element 1.1.1	Does prohibitive or regulatory AV legislation exist at the **state** level? (E.g., transit, funding, operations, infrastructure design and maintenance, safety, etc.)
Explanation	This index captures whether the state government has already passed laws regulating the selection, funding, design, safety, operations, and maintenance of AV/AV-based microtransit systems. Having existing laws and regulations could reduce possible legal problems and ambiguities. Potential investors could also plan for their AV programs according to the laws and regulations.
Scoring metrics	1. Yes, with law enforcement – 5 2. Yes, but only guidance – 4 3. Yes, but only for a testing/pilot project – 3 4. Not specified, but AVs are not prohibited – 2 5. Under preparation or debating – 1 6. Prohibited – 0
Element 1.1.2	Does the **county** government have AV-targeted ordinances?
Explanation	This index captures whether the county government has formulated ordinances guiding the design and implementation of AV or AV-based microtransit systems. The county government could adopt and enforce the state law.
Scoring metrics	1. Yes, with law enforcement – 5 2. Yes, but only guidance – 4 3. Yes, but only for a testing/pilot project – 3 4. Not specified, but AVs are not prohibited – 2 5. Under preparation or debating – 1 6. Prohibited – 0

Element 1.1.3	Does the **local** government have AV-specific rules or regulations?
Explanation	This index determines if a local government has already adopted regulations that instruct the usage and operation of AV or AV transit systems
Scoring metrics	1. Yes, with law enforcement – 5 2. Yes, but only guidance – 4 3. Yes, but only for a testing/pilot project – 3 4. Not specified, but AVs are not prohibited – 2 5. Under preparation or debating – 1 6. Prohibited – 0
Element 1.1.4	Do existing master/comprehensive transportation **plans** authored by city/state/county/transit/metropolitan planning organizations include AV or AV transit considerations?
Explanation	Most legislation regarding funding allocation require documented stakeholder support and, in some instances, financial partnering. This index captures, at the planning level, the funds and partnerships available for an AV system and if AV transit development is emphasized or prioritized.
Scoring metrics	1. Yes, there are specific AV/AV transit plans comprising critical elements like implementation goals, strategies, and timelines – 5 2. Yes, multiple comprehensive or transportation plans include or prioritize AV/AV transit development goals and strategies – 4 3. Yes, some plans have AV/AV transit considerations and implementation suggestions – 3 4. Yes, but only have general ideas of AV transit development – 2 5. AV considerations mentioned in government reports instead of plans – 1 6. No – 0
Element 1.1.5	Can the AV transit system align with **current traffic laws** and regulations?
Explanation	This index captures whether an AV transit system conforms to the current transportation laws, which may include: 1. Speed limit 2. Vehicle dimension 3. Safety devices 4. Lighting and signaling 5. Software updating requirements
Scoring metrics	1. [0, 5] depends on how many of the abovementioned rules are met. If a particular rule was not met, a 0.5 will be deducted. 2. The element might not be applicable if there are no traffic laws in place.
Criterion 1.2: Government and administrative support for AV-based microtransit systems	
Element 1.2.1	Does the local government entity or the designated department of transportation’s district possess a dedicated AV or AV transit **department/office**?
Explanation	This index captures the level at which the government entity is equipped to manage and advance new AV or AV transit projects. Possessing a dedicated office reflects a higher determination in implementing AV services.
Scoring metrics	1. Yes – 5 2. Yes, but not dedicated – 4 3. Yes, but at an early stage of development – 3 4. Planned and ready to implement/establish – 2 5. Planned, but not yet implemented – 1 6. No office/department planned – 0

Element 1.2.2	Does the government entity possess AV **specialists** or **leads** responsible for the management and operations of an AV transit system?
Explanation	This index captures the level of expertise present within the government entity, important for its ability to operate and maintain an AV transit system. Having dedicated AV specialists or leads reflects a higher determination in implementing AV services.
Scoring metrics	1. Yes – 5 2. Yes, but has other secondary duties/titles – 4 3. Not primary dedication – 3 4. Under development, with a hiring plan in place – 2 5. No, but can find someone in charge when needed – 1 6. No – 0.
Element 1.2.3	Does the government agency have history of funding/supporting new transportation **initiatives**?
Explanation	This index examines whether a government agency is prone to fund a new transportation initiative, and dictates the level of documentation, correspondence, stakeholder support, and measures of effectiveness required for deploying an AV transit service.
Scoring metrics	1. Yes, fully covered/dedicated – 5 2. Yes, partially/depends on the elected governor/officer in charge – [1, 4] 3. No – 0.
Note	Different parties and interest groups might hold distinctive opinions on AV technology.
Element 1.2.4	Is it a **government-endorsed** program?
Explanation	This index captures the level at which the government entity has publicized its support for AV transit, e.g., leading/actively participating in the projects, formal declarations of support, dedicated AV funding programs, amendments to prohibitive legislation, etc.
Scoring metrics	1. Yes, led or actively engaged by the government – 5 2. Yes, government participates but does not lead – 4 3. Promoted or granted by the government – 3 4. Neither supported nor disallowed by the government – 2 5. No government involvement – 1 6. Against/criticized by the government – 0
Element 1.2.5	Does the government have a **history** of successfully passing new (or changing existing) transportation laws and polices?
Explanation	This index indicates the effectiveness and efficiency of a government entity in passing new transportation laws and/or amending outdated policies, revealing the government entity's ability to take the necessary steps to transition to AV transit systems. Past successes/failures could be a reliable predictor of future results.
Scoring metrics	1. Yes – 5 2. Depends on the elected governor/officer in charge – [1, 4] 3. No – 0.

Note. The table is a general scoring guide, which allows for customization in practice. Individuals who use the framework can keep one's score based on expertise and judgment. The final score of a project should be the result of aggregating and averaging the individual scores.

2. Literature Foundation of the Pillar

The literature foundation of developing Pillar 1 included the "Policy and Legislation" measures of AVRI reports (2020), as well as relevant questions about government endorsement and funding from FDOT's CAV report (2019). The two reports contained measures of the government's readiness and acceptance of AV transit systems regarding passing new regulations, revising existing laws, and awarding grants/funding. The AVEE Framework then took a step forward and emphasized that all levels of government that might engage, which improved comprehensiveness.

3. Data Requirements for Implementation

Users should conduct a literature review of the local, regional, and state transportation regulations, ordinances, plans, and news. Based on the findings, users could rate the corresponding elements objectively. For instance, in Florida, Governor DeSantis signed legislation (HB 1289) into law that authorized the operation of low-speed AVs in July 2021 (Hayes, 2021). When holding scoring workshops, the users could consult the transportation department in advance to determine each criterion and element's scores, thereby avoiding accidentally neglecting some materials and information used in the legislation process. For example, FDOT experts could tell if they had an AV affair specialist or an office (Element 1.2.2) and if they planned to endorse some new projects (Element 1.2.4). Having more participants at the workshop would also reduce potential bias.

4. *Pillar 2: Infrastructure and Technology*

1. Content, Scoring Metrics, and Explanations

The Infrastructure and Technology Pillar (Pillar 2) includes two performance-measuring criteria applicable to the AV transit system's surrounding environment:

1. infrastructure facilitating the AV-based microtransit system
2. quality of the AV

Essential to safe and reliable operations and to building community trust, this pillar (**Table 4-2**) measures the quality and completeness of the infrastructure surrounding an AV-based microtransit project and the AV itself, mainly focusing on the roads and environment that will run AV shuttles to assess for preparedness and compatibility. The guiding assumption, supported by real-world cases like Move Nona, is that an AV shuttle can perform like a regular minibus, which requires at least the same operational environment. Hence, this pillar checks whether a new AV project meets those requirements or offers extra accommodations to enhance operation.

Table 4-2

Pillar 2: Infrastructure and Technology

Criterion 2.1: **Infrastructure to facilitate the AV-based microtransit system**	
Element 2.1.1	What is the roadway's **Pavement Condition Index** (PCI) score?
Explanation	This performance measure adopts the ASTM's (2020) PCI to measure road quality. PCI is a numerical index used to indicate a pavement section's condition by assigning it one of seven classifications (see **Figure 4-3**): Good (85-100), Satisfactory (70-85), Fair (55-70), Poor (40-55), Very Poor (25-40), Serious (10-25), and Failed (0-10). **Figure 4-3** An Example of PCI Assessment  PCI = 88 PCI = 55 PCI = 5 Note. From PCI survey Procedure [Photograph], by Tennessee IDEA, n.d., (https://idea.appliedpavement.com/hosting/tennessee/pavement-inspection/pci-review/overview.html

Scoring metrics	PCI's calculation method is a visual survey of the amount and types of distress in a pavement. When applying the PCI score to the element: 1. For roadways within AV transit system operations with a PCI score of Good, Satisfactory, or Fair, the criterion score is calculated by converting the PCI score from a [0-100] scale to a [0-5] scale; divide PCI score by 20. 2. The criterion will receive a zero for roadways with a PCI score of Poor or below (a PCI score of 55 to 0).
Note	Like traditional vehicles and buses, AV shuttles can operate on regular roads, but their advanced radar/lidar systems are sometimes more sensitive to obstacles and pavement distress. A good PCI score can offer a minimum road quality guarantee for implementing an AV service.
Element 2.1.2	Does the **roadway design** impede AV operations?
Explanation	This element focuses on roadway design that accommodates AVs and identifies atypical roadway design features that may hinder AV operations, which may include: 1. Vertical horizontal variations present in roundabouts and intersection, e.g., speed bumps, truck aprons, raised crossings, speed tables. 2. The presence of traffic/bicycle separation methods, e.g., flexible delineators and raised curbs. 3. The presence of landscaping/trees adjacent to AV lanes with the potential to obstruct sensors.
Scoring metrics	A visual survey of the routes to identify the abovementioned obstacles is needed. 1. Roadways without street design features that block the AV operation – 5 2. Roadways with minor issues (e.g., trees distract the sensors) – 4 3. Roadway design issues that need moderate/major/full fixing or upgrading, depending on time cost and budget – 1/2/3 4. Roadways unfit for AV operation or too expensive to upgrade – 0
Note	While many vertical and horizontal elements listed above improve the safety of vehicle/bicycle/pedestrian travel, their placement and use may not be conducive to AV sensors/operations.
Element 2.1.3	Do **street signs** impede AV operations?
Explanation	This element captures the extent to which street signs (e.g., parking, speed, wayfinding, traffic guidance signs) are clear, visible, and consistent for autonomous detection and decision-making. Examples of related issues may include: 1. Signs lack contrast, use of stylized lettering, highly reflective signage, inconsistent wayfinding signage (e.g., variable use of state/city/county naming conventions and different fonts and styles). 2. Roadway marking have visible wear, or markings are adjacent or perpendicular to travel lanes with the potential to interrupt proper sensor readings (e.g., stop bars, bicycle lane buffers, and crosswalks). 3. Crosswalk markings have high levels of wear or above-average reflective properties.
Scoring Metrics	A visual survey of the routes to identify the abovementioned obstacles is needed. 1. Street signs without abovementioned issues blocking AV operation – 5 2. Street signs with minor issues – 4 3. Street sign issues that need moderate/major/full fixing or upgrading, depending on time cost and budget – 1/2/3 4. Street signs unfit for AV operation or too expensive to upgrade – 0

Element 2.1.4	Is the supporting **infrastructure** ready to accommodate AV transit?
Explanation	This index captures the extent to which there is a network of supporting infrastructure to accommodate AV transit operations and encourage AV usage. Some key features are (see **Figure 4-4** for an example): 1. Bus bays/pull-outs 2. New, dedicated AV transit lanes 3. Original street with more multiple lanes 4. Original streets have dedicated bike/pedestrian lanes 5. Posted speeds higher than AV transit travel speeds 6. Parking spaces for cars and bikes (to assist trip connection) **Figure 4-4** An Example of Street Suitable for AV Shuttles  Note. The inbound lane (on the left) with an existing loading zone or space for a bus bay is suitable for AV operation. The outbound lane (on the right) is not because an AV stopping and loading passengers would block traffic. Own Work.
Scoring metrics	1. Infrastructures with major/moderate/minor/no challenges or upgrade needs will receive, depending on time, cost, and budget, a score of 1 to 5. 2. Identified infrastructure challenges that require costlier solutions, such as two-lane roadways without (or impossible to add) bus bays/pullouts and posted speeds above AV travel speeds, or an infrastructure challenge that otherwise requires construction or widening of lanes, should receive a score of 0. 3. The absence of dedicated transit lanes and/or separated bicycle/pedestrian lanes does not guarantee a 0. 4. If the road network of neighborhood does not meet the minimum requirement for operating a bus, it would receive a score of 0. Please refer to roadway owner agency guidance for traveling public acceptable levels of service. For example, FDOT's level of service targets for the state highway system are "D" in urbanized areas and "C" outside urbanized areas (Office of Systems Planning, FDOT, 2019).
Note	Low AV transit travel speeds and delayed stopping/turning movements present challenges on two-lane roadways without bus bays. Therefore, having the above-listed features are critical to infilling a new AV system and attracting users.
Element 2.1.5	Can AV users get high-speed, reliable broadband **internet** coverage?
Explanation	The success of AV operations is closely associated with the resilience, redundancy, and speed of internet. AV transit users often demand an app showing real-time locations of the vehicles and schedules. Determining the "success" relies on identifying existing 4G/5G or wifi technologies with faster speed available within the AV transit systems, particularly at the AV stops or even along the routes.

Scoring metrics	1. High-speed free wifi coverage at AV stops (paid by the operating company or the community) – 5 2. No free wifi but with good 4G/5G coverage in the service area – 4 3. Internet speed meets 3G standard – 3 4. Internet speed meets the basic requirement (see note below) to run the AV service's app and interactive maps – 2 5. Partial/unstable internet coverage in the area – 1 6. No coverage, or coverage too slow – 0.
Note	The minimum internet speed requirement here is the speed of 3G networks, which is about 3.1 megabits per second, allowing internet surfing and app usage. If the AV transit system is a fixed-route shuttle service with schedule provided, this criterion could be omitted.
Criterion 2.2: Quality of the autonomous vehicle	
Element 2.2.1	Do AVs have advanced vehicular **devices** supporting driving automation?
Explanation	This index measures whether an AV has a complete set of advanced devices supporting SAE's level four of driving automation, enabling 3D vision, environment recognition, and real-time obstacle detection and prioritization. Critical features may include: 1. driveline/power system performance 2. high-voltage battery 3. steering, braking, charging systems. 4. Lidar sensors 5. Detection lasers 6. Odometry 7. GNSS antenna 8. Stereovision cameras
Scoring metrics	1. AV programs use models that have passed all tests or been successfully implemented elsewhere, including Navya's Arma, EasyMile's EZ10, Local Motor's Olli, and Baidu's Apolong – 5 2. AV programs use new models matching the abovementioned successful AV shuttle models but require additional testing – 4 3. AV programs use new models that meet the ISO 22737:2021 minimum requirements – 3 4. AV models have failed to meet the SAE level four requirements – 0
Note	Experts and testing runs are needed when making decisions and evaluations.
Element 2.2.2	Have the AVs passed road and performance **tests**?
Explanation	This index examines whether an AV can pass road and performance tests and is ready to set out. Models successfully implemented elsewhere include Navya's Arma, EasyMile's EZ10, Local Motor's Olli, and Baidu's Apolong.
Scoring metrics	1. Models have passed local road and performance test – 5 2. Models have been successfully implemented in other places with similar road conditions/environment – 4 3. Models have succeeded elsewhere but need minor modification and localization – 3 4. Moderate modification needed – 2 5. Major modification or improvement needed – 1 6. Otherwise – 0

Note.: The table is a general scoring guide, which allows for customization in practice.

2. Literature Foundation of the Pillar

The primary sources supporting this pillar are the “Technology” and “Infrastructure” measures of the AVRI reports (including street readiness and broadband service quality), ASTM’s pavement condition index, the International Standard ISO 22737:2021(E), and other urban design codes of American cities. FDOT experts recommended the transportation infrastructure features listed in 2.12 to 2.14.

3. Data Requirements for Implementation

For criterion 2.1, users shall perform multiple onsite visual surveys to assess the road pavement condition, infrastructure design and completeness, and internet speed and coverage. For criterion 2.2, to see a complete list of advanced equipment of a level four SAE AV shuttle model, one may refer to documents like Navya’s owner’s manual for details and parameters. Otherwise, users may consult AV engineers or refer to the ISO 22737:2021(E) standard and assessment procedures if a project is not using models that have been proven reliable and successful.

5. Pillar 3: Service and Management

1. Content, Scoring Metrics, and Explanations

The Service and Management pillar (Pillar 3) has two performance-measuring criteria:

1. service quality of the AV-based microtransit system
2. management quality of the AV service provider

This pillar (see **Table 4-3**) is critical because the service quality of an AV-based microtransit system can directly affect user experiences, especially when introducing something novel to the public. At the same time, the management quality of the AV service provider determines whether the AV program can function correctly and address problems in a timely fashion.

Table 4-3

Pillar 3: Service and Management

Criterion 3.1: Service quality of the AV-based microtransit system	
Element 3.1.1	Is the AV-based microtransit service **proximate** to the community?
Explanation	This index reflects the relative convenience of accessing the AV shuttle as a transit mode choice, measuring how many households/residents live within walking distance (½ mile radius area or a 10-minute walk) of an AV service stop, in the case of hail-and-ride services, its route.
Scoring metrics	1. If the AV-based microtransit service offers a door-to-door pick-up and drop-off (no need to walk), the element receives a score of 5. 2. If the AV-based microtransit service is fixed-route with stops, then convert the percentage of households within walking distance of the AV stops over the total household number to a scale of zero to five. 3. One alternative is to conduct a community survey and estimate the percentage of respondents who live within walking distance of getting the AV service, and then convert the result to a scale of zero to five. $\frac{\text{Households or Respondents living in the service area}}{\text{Total Households or Respondents}} \times 5$
Element 3.1.2	Can the AV-based microtransit service let users travel **faster**?
Explanation	Travel time is a principal measure of public transportation service. People who used the framework could estimate the travel time difference based on the AV speed and distance or take AV rides in person.
Scoring metrics	1. 25%+ faster than the current travel time – 5 2. 5-25% faster than the current travel time – 4 3. 0-5% faster than the current travel time – 3 4. Same as current – 2.5 5. 0-5% slower than the current travel time – 2 6. 5-25% slower than the current travel time – 1 7. 25%+ slower than the current travel time – 0

Element 3.1.3	Is riding the AV-based microtransit service **comfortable**?
Explanation	This index measures the experience of riding in an AV shuttle. The measurements are similar to conventional cars, including: 1. The convenience of door access 2. Interior space (head and legroom) 3. Smoothness of the ride 4. Seat size and quality 5. Noise level when riding
Scoring metrics	1. Prepare a community survey targeting AV riders/passengers. 2. Use one or more attitude statement questions to ask the respondents about the five abovementioned aspects of comfort levels, using 1-5 Likert scale (from “Strongly Disagree” to “Strongly Agree”) for answer options. 3. Sample questions could include: “I think the cabin size is spacious”; “I think the seats are comfortable”; “I think the noise is finely controlled when riding.” 4. Assign values 1-5 to match those results (converting ordinal data to numerical data) and obtain mean and mode outcomes. 5. Find the average of the outcomes to be the element score.
Note	1. For assisting vendor selection: users could refer to the standards of bus entrance in the research area and seat pitch/width of bus (typically 39 inches wide) or major airlines. 2. An AV without ADA accommodation features (a lift ramp or a wheelchair space) can only get a maximum score 2.5.
Element 3.1.4	Does the AV service have a high-quality **smartphone app**?
Explanation	This index captures whether an AV-based microtransit system has a smartphone app/platform to help trip planning more efficient and precise. Two minimum functions are: 1. A real-time map showing the locations of all the stops and vehicles 2. Schedules of all vehicles and each stop Two recommended functions are: 1. A straightforward user interface 2. Multiple languages (at least English and Spanish in the United States)
Scoring metrics	1. An app with a complete set of functions, including on-demand ride requests – 5 2. An app with at least the two minimum functions and one of the recommended functions – 4 3. An app with the two minimum functions only – 3 4. An app with problems impairing one of the minimum functions – 2 5. An app with problems impairing both minimum functions – 1 6. No smartphone app or the app is not working – 0
Note	The AV shuttle service provider should also print and place service maps and schedules at all AV stops, helping people with no smartphones.
Criterion 3.2: Management quality of the AV-based microtransit system	
Element 3.2.1	Is there a professional **management** team operating the system?
Explanation	This index captures whether the AV system is professionally operated with good quality and high standards, with duties such as cleaning the cabin, keeping the data, marketing, networking, and problem-solving.

Scoring metrics	1. Yes – [3, 5] 2. Under development – [1, 3) 3. No – 0
Element 3.2.2	Is there a routine **training** program for managers, operators, and engineers?
Explanation	This index captures the AV vendor's focus on education and preparedness. A training program ensures that managers, operators, and engineers are knowledgeable about AV system operations and understand how to respond to unexpected disruptions accurately and rapidly.
Scoring metrics	1. Yes – 5 2. Yes, but with high employee turnover rate – 4 3. Yes, but has no routine – 3 4. Occasionally – 2 5. Rarely – 1 6. No – 0
Element 3.2.3	Does the AVs receive sufficient and professional **maintenances**?
Explanation	This index captures the AV vendor's regular maintenance adherence. Users need to ask the operating company for data.
Scoring metrics	1. AVs receive required inspections and maintenances recommended by the manufacturer on a regular basis – 5 2. AVs receive required inspections and maintenance, but the latter was not from the manufacturer – 4 3. AVs receive inspections and maintenance occasionally – 3 4. AVs receive inspections and maintenance rarely – 2 5. AVs only receive maintenance when problems occurred – 1 6. No maintenance – 0
Element 3.2.4	Availability of ridership **data** and operation log/records?
Explanation	This index captures the availability of AV ridership and operations data provided by the AV vendor to the public. Besides test/pilot programs, government funding will require ridership and incident data reports. Furthermore, an AV vendor looking to market the acceptance and utility of their system needs to demonstrate this success by transparently sharing this information.
Scoring metrics	1. The AV vendor keeps complete ridership and operations data, which are open to the public – 5 2. Data are not published but available by request – 4 3. Data is only available to designated groups – 3 4. Part of the data is available to designated groups – 2 5. Withholding data – 1 6. Absence of data – 0
Element 3.2.5	Can the operator monitor and provide timely **responses** when incidents happen?
Explanation	This index captures the capability of the offering timely solutions or technical support (at least car towing service) by the vendor and operation team when facing accidents or incidences.
Scoring metrics	1. Immediate remote technical support and adequate number of prepared field service technicians – 5 2. Timely remote and field technical support available but contracted out – 4 3. Remote and field technical support available but experiencing service delay – [2, 3] 4. Either remote technical support or field service is not available – 1 5. Incidents causing service cancellation – 0

Note. The table is a general scoring guide, which allows for customization in practice.

2. Literature Foundation of the Pillar

The research team developed the first criterion based on a collectively accepted standards, e.g., the expectation that a half mile can be considered walkable. Building the criterion also depended on data availability, where ridership and household data were usually convenient to gather. For criterion 3.2, the team selected the measures inspired by Beep, the leading AV service management company in the United States.

3. Data Requirements for Implementation

Element 3.1.1 needs census data and the community's GIS shapefiles. 3.1.2 to 3.1.4 need a community survey. Criterion 3.2 requests the users to observe or investigate the service provider.

6. Pillar 4: Financial Sustainability

1. Content, Scoring Metrics, and Explanations

The Financial Sustainability pillar (Pillar 4) contains two performance-measuring criteria:

1. the AV program's funding security and stability
2. the possibility of becoming a long-term transit option

This pillar (**Table 4-4**) is imperative since an AV transit program's successful implementation and continued operation require an enormous financial investment. Even a pilot program could not sustain itself without adequate, stable funding sources. A lack of funding might also reduce service time, area, and quality. Besides, financial sustainability is a pivotal factor in determining whether an AV transit program could replace or complement a conventional bus system and thus would be worth keeping in the long run by a municipality or county. This pillar attempts to explore methods to assess pilot/demonstration projects and long-term, commercial programs.

Table 4-4

Pillar 4: Financial Sustainability

Criterion 4.1: Funding security and stability of the AV-based microtransit system	
Element 4.1.1	How **sufficient** is the proposed budget of the AV project?
Explanation	This criterion measures whether an AV-based microtransit project's budget is sufficient (covering all the costs) for its designated testing/demonstration period, or potentially in the long run. Literature suggests that almost all AV-based microtransit projects worldwide were testing/pilot programs, and many were free, implying that the success of such projects relied entirely (or at least extensively) upon stable funding sources, including the government, private investors, or public-private partnerships.
Scoring Metrics	1. A self-sufficient AV program (e.g., operating revenue, and advertising income) – 5 2. A partially self-funded AV program (has some operating revenue but still relies on venture capital investments or business loans) – 4 3. An AV program that primarily relies on venture capital investments and business loans – 3 4. Otherwise – 0 For a pilot/testing/demonstration AV project: 1. With promised/received funding covering the entire estimated cost – 2.5 2. With cost over funding – 0
Note	Users need to contact the operation company if the data (funding amount and operational cost) is not open to the public.

Criterion 4.2: Possibility of AV service becoming a long-term transit option	
Element 4.2.1	From the **financial sustainability** perspective, what is the AV-based microtransit system's potential of becoming a long-term public transportation option?
Explanation	Since the purpose of implementing an AV-based microtransit system is to provide a new public transit option for residents, it is essential to assess its effectiveness and whether it can play the same role as a bus system. If it can, the AV system is worth turning into a long-term transit method capable of receiving financial support from transit providers or the government. The suggested method is to compare the expenses of operating an AV shuttle and a public bus deployed in the city/region over their vehicle-mile (vehicle miles traveled, or VMT), and the steps are as follows: 1. Identify the annual cost of an AV shuttle (the initial capital cost of purchasing the vehicle itself should be annualized over its lifecycle), and then divide it by its annual VMT. 2. Estimate the average annual cost of a city bus, including the capital cost (should be annualized over its lifecycle) and operating costs (fuel and employee wages and benefits), and then divide it by its annual VMT.
Scoring Metrics	If the estimated annual cost of an AV shuttle per VMT is: 1. Less than average annual cost per VMT of a city bus – 5 2. Equal to the average annual cost per VMT of a city bus – 4 3. 0 – 5% more than the average cost per VMT of a city bus – 3 4. 5 – 10% more than the average cost per VMT of a city bus – 2 5. 10 – 25% more than the average cost per VMT of a city bus – 1 6. 25%+ more than the average cost per VMT of a city bus – 0
Note	1. Users of the framework may adjust the range/interval of the cost gaps based on actual condition/needs. 2. The suggested life cycle of an AV shuttle, e.g., Navya Arma is 5 years. 3. The suggested life cycle of a city bus is around 10 to 12 years. 4. The city bus can be gasoline/diesel, hybrid, or electric buses depend on the actual condition, resulting in different costs. 5. The framework users can use the data of all city buses or buses in adjacent regions of the study area depending on availability.
Element 4.2.2	From the **transit system efficiency** perspective, what is the AV-based microtransit system's potential of becoming a long-term public transportation option?
	Since a city bus and an AV shuttle have different loading capacity and route length, it is also reasonable to compare their efficiency. Thus, the framework adopts the classic transit system efficiency indicator: transit passengers per VMT.
Scoring Metrics	If the transit passengers of an AV shuttle per VMT is: 1. More than the average passengers/VMT of a city bus – 5 2. Equal to the average passengers/VMT of a city bus – 4 3. 0 – 5% less than the average passengers/VMT of a city bus – 3 4. 5 – 10% less than the average passengers/VMT of a city bus – 2 5. 10 – 25% less than the average passengers/VMT of a city bus – 1 6. 25%+ less of the average passengers/VMT of a city bus – 0
Note	1. Users of the framework may adjust the range/interval of the cost gaps based on actual condition/needs. 2. The framework users can use the data of all city buses or buses in adjacent regions of the study area depending on availability.

2. Literature Foundation of the Pillar

When developing this pillar, the research team considered multiple methods, such as cost-benefit analysis and investment return studies, to evaluate whether an AV system could cover or partially cover its expenses under various scenarios and funding possibilities. If an AV-based microtransit service could become a long-term public transportation option, we could find alternative methods to evaluate financial sustainability at that time.

However, as mentioned in the table above, since most AV projects, including Move Nona, were free pilot/testing programs, they could not be self-sufficient. Additionally, even many conventional public transportation systems rely heavily on government subsidies or public-private partnerships. Thus, we have realized that at this stage, the AVEE Framework could only give scores of no more than 3 for all temporary AV projects (4 and 5 are good scores with positive implications).

Regarding an AV project's potential of becoming a long-term transit option, we compare it with the public bus system. Since an AV shuttle is smaller in size and often has a shorter operating route, we divide the operating costs and transit passenger numbers by VMT to normalize the unit, which are classic public transit performance indicators suggested by Vuchic (2007).

3. Data Requirements for Implementation

The first criterion needs fiscal reports provided by the AV operation company, indicating the overall budget (funding received or proposed) and the expenses. One may omit this criterion if the data involves proprietary business information or privacy concerns. For the second criterion, users look at whether an AV system could replace or become a part of the existing public transport system. Therefore, data needs require the financial report, ridership number of bus routes, and the VMT of the buses serving the study area from the relevant DOT. For example, to apply this pillar to the BUILD Grant project in Orlando, FDOT would ideally provide ridership data for the LYNX routes around Lake Nona.

7. *Pillar 5: Ridership and Community Impact*

1. Content, Scoring Metrics, and Explanations

The Ridership and Community Impact pillar (Pillar 5) has two performance-measuring criteria:

1. ridership impact of the AV-based microtransit system
2. community acceptance of the AV-based microtransit system

This pillar (Table 4-5) is critical because the actual ridership and community acceptance greatly determine the extent to which the public uses and acknowledges an AV-based microtransit system. In other words, improving the residents' satisfaction is pivotal to reducing resistance when advancing the AV shuttle system from a demonstration project to a long-term public transit service covering the entire neighborhood. This pillar's score and related findings directly reflect the real-world performance of an AV-based microtransit system.

Table 4-5

Pillar 5: Ridership and Community Impact

Criterion 5.1: Ridership impact of the AV-based microtransit system	
Element 5.1.1	What is the AV **ridership** trend?
Explanation	This index captures the variations in recorded ridership experienced by the AV-based microtransit system throughout the implementation lifecycle and whether the ridership of the existing transit system increases or decreases.
Scoring metrics	Make a best-fit line of the ridership data and calculate the slope. 1. If the slope result is positive, then add it to 2.5 (maximum is 5). For example, a slope of 0.5 leads to an element score of 3. 2. Otherwise, deduct the slope value from 2.5 (minimum is 0). For example, a slop of -0.5 leads to an element score of 2. $\text{Slope} = \frac{\sum\left((x-\bar{x})\times(y-\bar{y})\right)}{\sum(x-\bar{x})^2}$ x is the operation day number, and the ridership of a day.
Element 5.1.2	Can the AV-based microtransit system attract **repeat** passengers?
Explanation	This index captures an AV-based microtransit program's ability to retain users. It checks whether riders are willing to use the AV again.
Scoring metrics	1. Prepare a community survey targeting AV riders/users. 2. Use attitude statement questions to ask the respondents if they want to use the AV service again. 3. A sample question can be, "I plan to use the AV service again." 4. The answer choices can either be a 1-5 Likert scale, or "Agree/Disagree." 5. Find the percentage of the respondents with positive responses and multiply by 5 to arrive at the element score.

Element 5.1.3	Does the AV service **reduce** private car usage?
Explanation	This index captures how the AV-based microtransit system affects private car usage, signifying the importance of promoting an AV transit service.
Scoring metrics	1. Conduct a community survey to find the percentage of respondents (x) who have changed their travel method from driving to taking the AVs. Users can set a desired objective of car usage decreasing rate (y). 2. Divide x by y and multiply the product by 5.
Note	The outcome of the percentage of residents who have abandoned driving should be compared with the data provided by ACS (travel mode ratio shift) to determine credibility of the survey.
Criterion 5.2: Community acceptance of the AV-based microtransit system	
Element 5.2.1	Does the community think the AV-based microtransit system is **useful**?
Explanation	This index measures community residents' perceptions of an AV program to understand whether they believe it is a useful and convenient public transit option.
Scoring metrics	1. Prepare a community survey targeting all residents. 2. Use one or more attitude statement questions and a 1-5 Likert scale (from "Strongly Disagree" to "Strongly Agree"). 3. A sample question might be: "I think the AV service is useful," or "I think the AV service can let me travel more conveniently." 4. Assign values 1 to 5 to match those results (converting ordinal data to numerical data) and obtain mean and mode outcomes. 5. Find the average of the outcomes to be the element score.
Element 5.2.2	Are the riders/users **satisfied** with the AV-based microtransit service?
Explanation	This index measures the AV-based microtransit service riders/passengers' perceptions to understand whether they are satisfied.
Scoring metrics	1. Prepare a community servey targeting all residents. 2. Use one or more attitude statement questions and a 1-5 Likert scale (from "Strongly Disagree" to "Strongly Agree"). 3. Sample questions might be: "I am satisfied with the AV service," or "I think most of my expectations towards AVs have been confirmed." 4. Assign values 1 to 5 to match those results (converting ordinal data to numerical data) and obtain mean and mode outcomes. 5. Find the average of the outcomes to be the element score.
Element 5.2.3	Is an AV-based microtransit system a valuable neighborhood **asset**?
Explanation	This index measures whether an AV shuttle is a critical asset to the neighborhood and is a factor in attracting current and new residents.
Scoring metrics	1. Prepare a community survey targeting all residents. 2. Use one or more attitude statement questions and a 1-5 Likert scale (from "Strongly Disagree" to "Strongly Agree"). 3. Sample questions might be: "I think having an AV shuttle service can make a neighborhood more attractive or positively influence moving decisions." 4. Assign values 1 to 5 to match those results (converting ordinal data to numerical data) and obtain mean and mode outcomes. 5. Find the average of the outcomes to be the element score.

Note. The table is a general scoring guide, which allows for customization in practice.

2. Literature Foundation of the Pillar

The literature foundation of this pillar includes the performance criterion 14.1 of the UN SDG tool, which aids in assessing the transportation trends for conducting urban development projects, as well as other common standards of measuring ridership. Additionally, journal articles published by Feys et al. (2020), Wang et al. (2020), and Chan & Lee (2021) included survey questions targeted around community perceptions and acceptance of AVs and were also contributed to the development of criterion 5.2.

3. Data Requirements for Implementation

The ridership data will not be available before an AV project's implementation, e.g., the BUILD Grant project. It is only available for deployed projects, like the Move Nona system. Users can request the ridership data (trip numbers or passenger numbers) from the AV service provider or can otherwise estimate the ridership based on other similar services. For Pillar 2, users can develop a community survey on AV transit programs to learn people's perceptions of AV technology, service, and impact. Chapter 6 will analyze a sample survey.

8. *Customizing the AVEE Framework by Project Stage*

1. Overview

The AVEE Framework is also available for further customization according to users' distinct intentions and needs. In other words, a tailored version of the AVEE Framework focuses on and accommodates users' unique requirements at any unique point in the AV deployment timeline by only retaining relevant criteria and elements/sub-criteria. Tailoring the AVEE Framework would make the rating process more convenient by reducing the framework's length and complexity. Users can hold public/private workshops to decide collectively which criteria are worth keeping. Note that holding tailoring workshops is a usual approach when evaluating projects. **Figure 4-5** shows that using the UN SDG tool often involves multiple workshops to determine which SDG to explore and to select applicable criteria from hundreds of questions.

In this section, we offer three customized versions aimed at fulfilling three critical needs of the users. The needs are as follows:

1. *AV readiness* – evaluating the readiness of a community to attract an AV deployment
2. *Vendor selection* – selecting competing bids for service of a planned AV deployment
3. *Deployment evaluation* – evaluating the success of an AV deployment against the stated goals of the deployment

Figure 4-5

Examples of the SDG Tool Tailoring Workshops

Note. SDG Tool scoring workshops held by UN-Habitat. From SDG Tool [Photograph], by UN-Habitat, 2021, (https://www.globalfuturecities.org/sdg-project-assesment-tool).

2. Customized Framework for AV Readiness

Table 4-6 below explains how to customize the AVEE Framework to evaluate the readiness of a community when it is preparing for accommodating AV transit deployment or attracting investors to launch an AV-based microtransit system.

Table 4-6

Customized AVEE Framework – AV Readiness

	Evaluation framework for AV readiness
Description	This version evaluates the readiness of a neighborhood, corridor, town, or other general regions where route(s) have not yet been determined for implementation of an AV-based microtransit service.
Potential users	1. Communities evaluating self-readiness 2. Funding agencies prioritizing resources for a new AV project
How to score	1. Score each community individually across all criteria in each pillar. 2. Average the score of all criteria across all pillars. 3. Compare with other communities or prioritize improvements for readiness as desired.
How to use the score	1. A single community score serves as a gap assessment, identifying areas (i.e., pillar or criteria with relatively low scores) where additional actions could further support AV shuttle deployment. 2. Alternatively, multiple communities can be compared for prioritization purposes.
Applicable criteria	1. Pillar 1: 1.1.1 to 1.1.5, and 1.2.1 to 1.2.5 2. Pillar 2: 2.1.1 to 2.15
Reason	The first two pillars capture whether a community has government and legal support and check if the existing infrastructure systems could efficiently accommodate AVs. Higher scores mean less resistance.

Note. Users can add or subtract criteria depending on needs.

3. Customized Framework for Vendor Selection

Table 4-7 below explains how to customize the AVEE Framework when selecting competing bids for service of a planned AV deployment.

Table 4-7

Customized AVEE Framework – Vendor Selection

	Evaluation framework for vendor selection
Description	This version evaluates the suitability of a vendor for an identified project. 1. For example, this can help transportation authorities to determine which vendor and service to select from several options. 2. On the other hand, vendors may also use the tool to self-estimate the competency of their bids and products.
Potential users	1. Owner agency evaluating submitted bids 2. AV vendors/providers evaluating bid competency
How to score	1. A single community score serves as a gap assessment, identifying areas (i.e., pillar or criteria with relatively low scores) where additional actions could further support AV shuttle deployment. 2. Alternatively, multiple communities can be compared for prioritization purposes.
How to use the score	The score provides a comparison of potential vendors for project.
Applicable criteria	1. Pillar 1: 1.1.5 2. Pillar 2: 2.1.5, 2.2.1, and 2.2.2 3. Pillar 3: 3.1.1 to 3.1.4, and 3.2.1 to 3.2.5 4. Pillar 4: 4.1.1 and 4.2.1

Note. Users can add or subtract criteria depending on needs.

4. Customized Version for Deployment Evaluation

Table 4-8 below explains how to customize the AVEE Framework to evaluate the success of an AV deployment against the stated goals of the deployment.

Table 4-8

Customized AVEE Frameworks – Deployment Evaluation

	Framework for deployment evaluation
Description	This version evaluates and quantifies the deployment of an AV-based microtransit project against its stated goals.
Potential users	Owning or maintaining agency that seeks to evaluate project performance or identify areas for future improvement
How to score	1. Review the deployment objectives and compare them to the five pillars. 2. Select those pillars that align with the objectives. 3. Conduct a "Before" assessment, scoring the criteria in the selected pillars. 4. Average the scores within a pillar. 5. After the deployment period, conduct an "After" assessment, scoring the criteria in the selected pillars. 6. Average the scores within a pillar. 7. Compare the "Before" and "After" scores within each pillar. 8. If deployment is ongoing, use element scores from the second assessment to identify areas for improvement. 9. Repeat assessment as desired.
How to use the score	Comparing "Before" and "After" scores allows for measurement of project's impact. Midpoint evaluations allow for identification of areas of improvement.
Applicable criteria	All elements are applicable. Users can select based on needs.

Note. Users can add or subtract criteria depending on needs.

Chapter 5. From the BUILD Grant Project to Move Nona

1. Overview

Chapter 2 introduced the AVEE Framework and its customized versions in detail. Considering its innovation and necessity, applying the tool step by step to an existing AV project as a case study for verification and refinement is thus cardinal.

One original objective of the research (Task 2) was to summarize the implementation process of the BUILD Grant project in Lake Nona by documenting challenges faced, solutions proposed, and the results comprised between the stakeholders. At the same time, the research attempted to apply the AVEE Framework to an AV transit system funded by the BUILD Grant to gain valuable experiences applicable to other agencies in Florida and to the nation more broadly as it eyed similar AV-based microtransit services.

However, because the BUILD Grant project on AVs was not awarded at the time of drafting this report (November 2022), the research team selected the Move Nona AV shuttle program to serve as its case study. The Move Nona program is currently in operation in Lake Nona. It is funded by the Tavistock Development Company group and managed by Beep. As a local AV shuttle program with three years of safe, successful operation records servicing thousands of local and visiting passengers, it was worth investigating and learning.

This chapter will provide summaries of the proposed of the BUILD Grant LAMN project and the Move Nona AV shuttle program before explicitly offering reasons for analyzing the latter.

2. The BUILD Grant Project

Since 2009, the USDOT has launched considerable Better Utilizing Investments to Leverage Development (BUILD) Transportation Discretionary Grant projects to fund investments to achieve national objectives in crucial transportation infrastructures like roadways, rail, transit, and ports.

In 2019, Orange County, Florida, received a BUILD Grant award of $20 million to develop and improve a “local alternative mobility network” (LAMN) that mainly accommodates pedestrians, cyclists (both casual and commuter), and AV transit systems to reduce automobile dependencies, enhance road safety, and alleviate environmental concerns. Specifically, the funding will support the planning, design, and construction of vital civil and transportation infrastructures, e.g., shared mobility lanes, dedicated rights-of-way, sheltered waiting areas, upgrades to existing pedestrian and bicycle paths, and a head-end mobility hub.

Most importantly, one of the main objectives of the grant is to support infrastructure development that facilitates local AV adoption, and the chosen site will be the Lake Nona neighborhood (Orange County, 2019). If implemented, the project would be a pivotal move representing American cities exploring an automated, alternative transportation mode to foster smart traveling and elevate the quality of life. The passenger facilities, roadway upgrades, and dedicated microtransit facilities would help promote the new travel mode, minimize conflicts between vehicles and pedestrians, and help develop best practices that could support future deployments nationwide.

Unfortunately, delays in implementing the BUILD Grant made it impossible to assess the proposed AV routes and their supporting infrastructure. Because of this, the study team decided to focus its research on the existing Move Nona program in Lake Nona, described below.

3. Move Nona by Beep

The original purpose of this research project was to gain experience in enabling similar AV-based microtransit programs, including the BUILD Grant LAMN project, and in facilitating potential users to thoroughly learn and understand the applications of the AVEE Framework. As the BUILD Grant LAMN project has not yet launched any AV shuttle programs, and the research team could not build knowledge or develop a framework based on a proposal. Instead, the team required an actual program to evaluate whether implementing other potential AV shuttle programs would result in success or failure. Although we could assess a hypothetical project's potential impacts or readiness, applying the full framework to an existing AV service/program would still be better.

As an alternative, Beep's Move Nona AV shuttle system, also launched in Lake Nona, Orlando, in September 2019, has become the new research target. Comparing with the other AV shuttle programs, Move Nona has the following advantages:

1. It has been operating for almost three years, safely carrying over 470,000 passengers in Lake Nona.
2. It was the most extensive and longest-running autonomous shuttle network at one location in the United States, connecting residential, commercial, retail, recreational, and medical services.
3. It was the fruit of private investment and government support and could thus serve as an example of successful public-private collaboration.
4. It shared the same site (Lake Nona) with the proposed BUILD Grant project (just smaller in scale of the service area and fleet size), implying that the two projects might have similar community impacts, reducing the possibility of false analogy if choosing a project somewhere else.

By discussing the viability, research value, and opportunities to gather critical data, the research team, project manager, and other project support team have agreed that the Move Nona AV shuttle program could be a quintessential case study that would support the design and implementation of the AV Effectiveness Evaluation Framework.

Chapter 6. Move Nona Case Study: Baseline Data & Site Analysis

1. Overview

To identify the data and material needs for applying the AVEE Framework to a particular AV-based microtransit project in order to assess its impact and effectiveness, researchers and users of the tool need to conduct a preliminary baseline data analysis of the study area. This analysis is a critical preparation step for thoroughly understanding the study area's existing demographic, socioeconomic, and transportation characteristics.

Additionally, if a community survey collecting sample data is involved in measuring specific criteria of the framework in a later research stage, a statistical test comparing how well the characteristics of the population learned from here and those of the sample match is a must. Therefore, this chapter presents a preliminary existing condition analysis using Lake Nona as a demonstration.

The data sources are as follows:

1. Study area: (1) physical boundary of the neighborhood, (2) census tracts covered by the neighborhood, and (3) designated land use
2. Demographic characteristics: (1) population growth trend, (2) population by age groups and gender, and (3) racial distribution
3. Socioeconomic and housing: (1) median annual household income trend and (2) monthly housing costs
4. Transportation and commute mode: (1) primary means of travel, (2) inflow and outflow of workers, and (3) Move Nona's AV-based microtransit shuttle routes

2. *Study Area: Lake Nona*

Lake Nona, in Orlando, FL, is a 17-square-mile mixed-use community built by an international real estate group, the Tavistock Development Company Development Company. Lake Nona is one of the fastest-growing and fastest-selling central Florida communities, encompassing thoughtfully designed houses, top-rated schools, and business, research, and retail clusters (Orlando Sentinel, 2012). **Figure 6-1** displays the suggested boundary of the Lake Nona community (the neighborhood is the enclosed residential, mixed-use areas). The Orlando International Airport, MCO, is contiguous to the neighborhood's northwest corner, with an estimated vehicle travel time of 10 minutes (four miles) between the two destinations.

Figure 6-1

Map of the Lake Nona Region

Note. The base satellite image is from *Google Maps*.

In 2021, Tavistock Development Company and the city of Orlando marketed the Lake Nona neighborhood, which is the residential area within the region, as “the model for technology, innovation, and community.” They highlighted its proximity to the Lake Nona Medical City (marked by the yellow circle in **Figure 6-1**), a 650-acre health and life sciences park and home to several public and private biomedical research institutions and education centers, including the University of Central Florida’s College of Medicine, the Sanford Burnham Prebys Medical Discovery Institute, and the VA Medical Center (city of Orlando, n.d.). **Figure 6-2** is the Lake Nona’s Community Guide Map, first created by Tavistock Development Company to illustrate the public and private interconnectivity of the region.

Figure 6-2

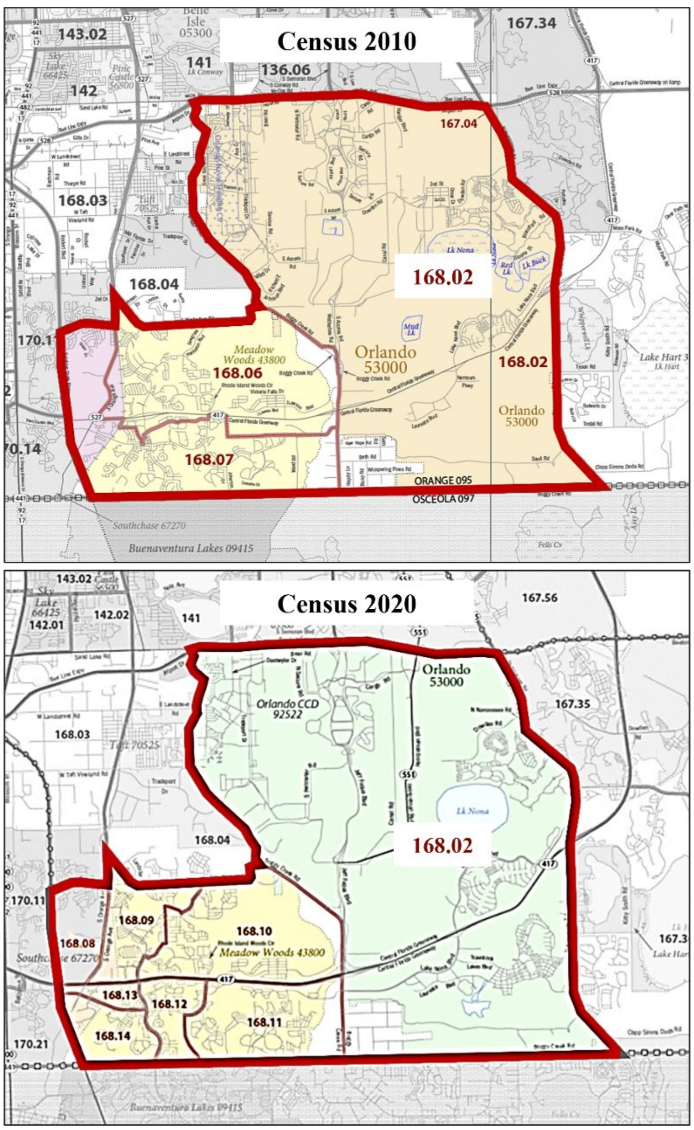
Lake Nona’s Community Guide Map

Note. This map shows the main residential (dark blue), commercial (light blue), social (green and grey), and medical research (orange) clusters. Illustration by Tavistock Development Company (2019), courtesy of Lake Nona.

Figure 6-3 below overlays the study area's physical boundary (red borders) by the 2010 (top) and 2020 (bottom) census tract maps. The 2010 tracts deviate from the 2020 tracts, in that 168.06 and 168.07 are replaced by seven new tracts, with numbers ranging from 168.08 to 168.14. Since the central residential and mixed-use developments suggested by the neighborhood map (**Figure 6-1**) and the community map (**Figure 6-2**) both fall within the census tract 168.02 (**Figure 6-3**), the demographic and socioeconomic analysis (presented in the next section) primarily focuses on that census tract. Data analyses of surrounding areas and Orlando are for comparison purposes.

Figure 6-3

Lake Nona Neighborhood on 2010 and 2020 Census Tract Maps



Note. From the *US Census Bureau*'s MAF/TIGER database (TAB10ST12 & TAB20).

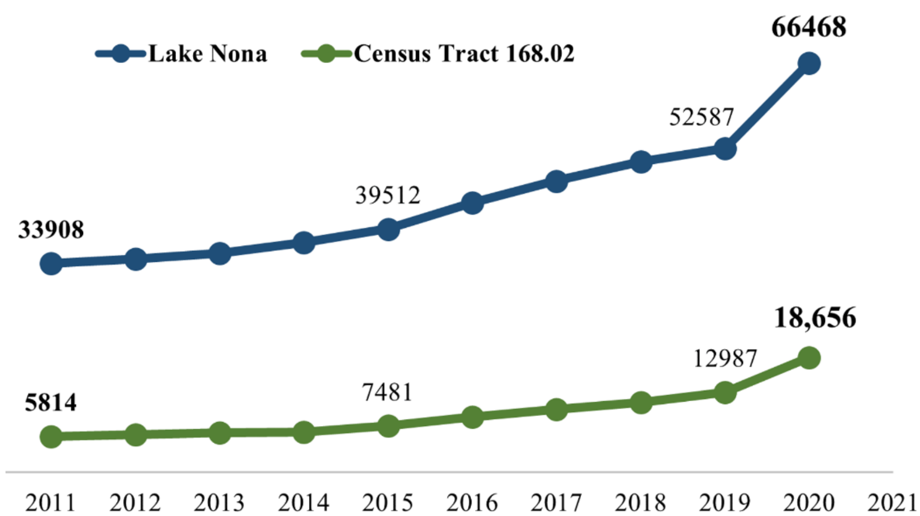
3. Demographic Characteristics

1. Population Growth Trend

Figure 6-4 illustrated the population growth trends from 2011 through 2020 for the overall Lake Nona Region and census tract 168.02. Data was sourced by the American Community Survey (ACS) for 2011 to 2019 and from United States Census for 2020 (US Census Bureau).

Figure 6-4

Historical Population of Lake Nona Region and Census Tract 168.02



Note. Lake Nona's population had an average annual growth rate (AAGR) of 7.2%. Census tract 168.02's population had an AAGR of 12.9%. Data retrieved from the ACS and Census (US Census Bureau).

Further analysis of the population growth trend displayed in **Figure 6-4** underscored the inherent relationship between housing/commercial growth and the surrounding community, supporting potential demand and need for additional mobility options. Within a decade (2011 to 2020), the Lake Nona region's overall population nearly doubled (1.96 times), from 33,908 to 66,468, with an astonishing annual growth rate of 9.6%, as compared to the national rate of 7.4% (US Census Bureau). Meanwhile, census tract 168.02's population independently increased by an even greater 3.2 times, going from 5,814 to 18,656, with an annual growth rate of 22.1%. As a result, the population share of census tract 168.02, in comparison to the overall Lake Nona Region, increased from 17.1% to 28.1 %, reflecting the tremendous development impact of Tavistock

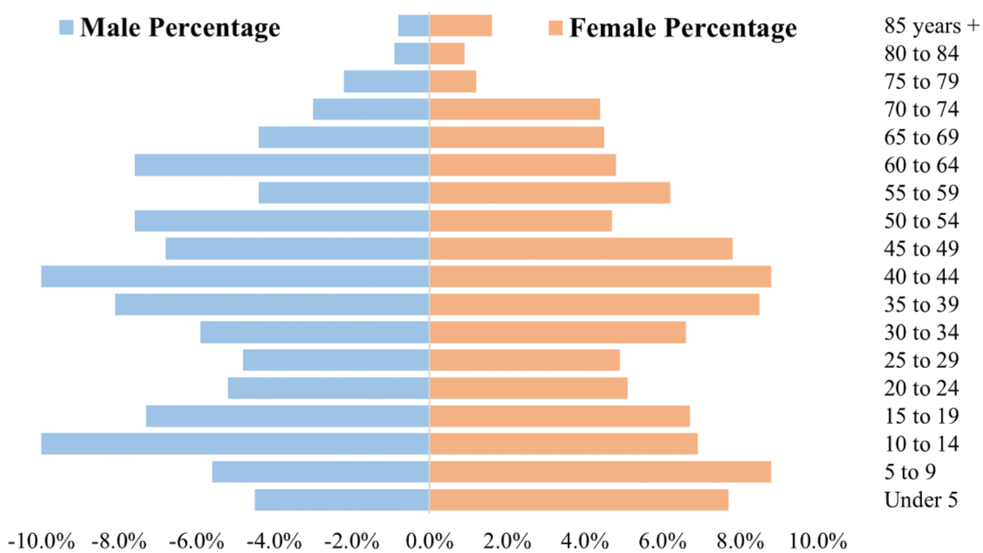
Development Company's investment in the study area. However, it was noticeable that the sharp population spike from 2019 to 2020, irrespective of external migratory forces, might also have been influenced by ACS data margins of error (e.g., +/- 1,689 for tract 168.02 in 2019).

2. Age and Gender Distribution

Below, **Figure 6-5** presents a graphic population pyramid of the age-sex distribution in the Lake Nona Region in 2019 (ACS, US Census Bureau).

Figure 6-5

Population Pyramid for Lake Nona Community, 2019



Note: Data retrieved from the ACS 2019 (US Census Bureau).

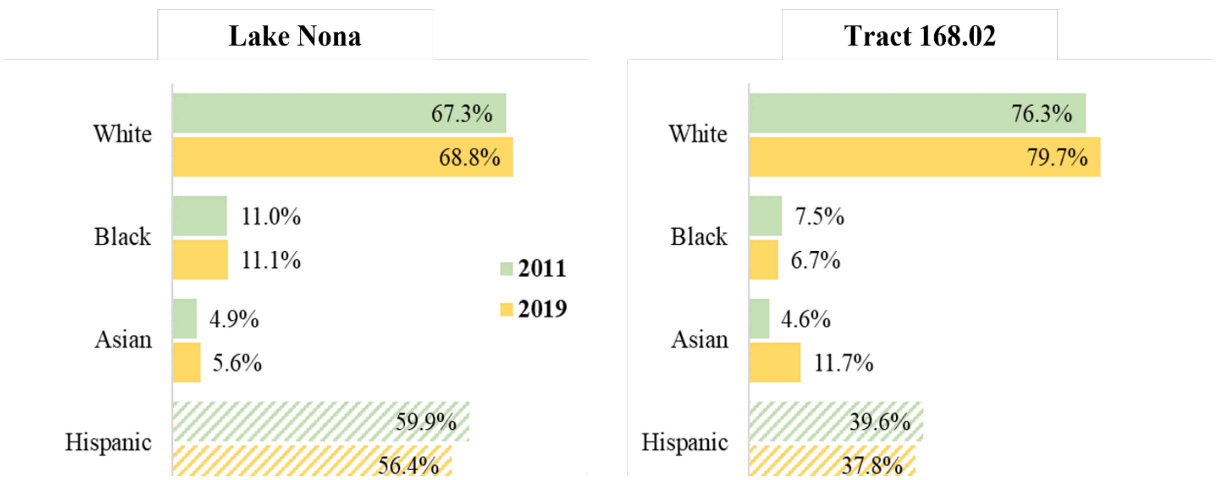
A review of **Figure 6-5** above reveals the male-to-female ratio to be relatively even, at 48.6% female and 51.4% male. Furthermore, the age group pattern implied that Lake Nona was a moderately young community, consisting primarily of working-age residents (15–64) and youths (0–15). This pattern of an aggregation of the youth dependency rate (29.5% [proportion of youth to working age]) and old-aged dependency rate (15.6% [proportion of old-aged to working age) gave us a more comprehensive understanding of the proportion of Lake Nona inhabitants that were not active in the labor force. Of the study area, 45.1% (total dependency rate) of the population was non-working. We could then infer that 54.9% of the population was of working age and, in theory, supporting 45.1% of the population assumed to be children or retired persons. In comparison, the United States, driven by an increase in the above-65 population, held a total nationwide dependency rate of 53.7% in 2019 (US Census Bureau).

3. Race and Ethnicity

Figure 6-6 below summarizes the race and ethnicity status of the Lake Nona Region (left) and census tract 168.02 (right) from 2010 to 2019. Note: The Hispanic group is an ethnic classification separate from the racial classifications, thus resulting in totals greater than 100%.

Figure 6-6

Racial Distribution of Lake Nona vs Census Tract 168.02, 2010 and 2019



Note. Data retrieved from *ACS* 2011 and *ACS* 2019, by US Census Bureau.

A review of the figures indicates that the Lake Nona Region was predominantly White, with a significant percentage of Hispanic residents. Contrasting Lake Nona Region (left) and census tract 168.02 (right), we observed deviations in race segment proportions, namely of an increased ratio of White and Asian populations and reduced percentages of African American and Hispanic residents (60% of census tracts 168.06 and 168.07 in 2019). Although the most drastic increase in population from 2011 to 2019 was within the Asian segment of census tract 168.02, which changed from 4.6% to 11.7%, the overall proportions of the three major racial segments have not changed saliently within Lake Nona. In contrast, Orlando's racial distribution comprised 61.3% White, 24.5% African American, 4.2% Asian, and 32.6% Hispanic (US Census Bureau, 2021).

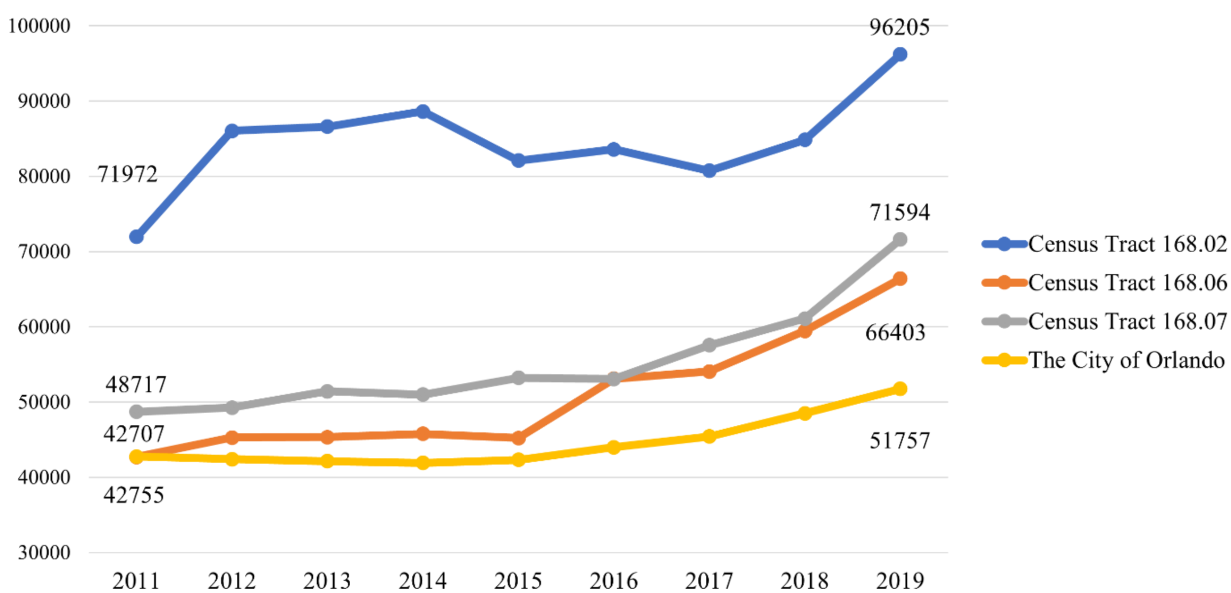
4. Socioeconomic and Housing

1. Median Household Income

Tavistock Development Company (2019) marketed Lake Nona as one of the "top-selling master-planned communities in Orlando and the United States." The new development has intrigued more than 500 new families each year. Due to an average purchasing price of over half a million dollars, Lake Nona has become a relatively high-end neighborhood with expensive single-family homes and condominiums. These claims appeared to hold true, as demonstrated by **Figure 6-7**.

Figure 6-7

Median Household Income of Lake Nona Region vs Orlando, 2011 to 2019



Note. Data retrieved from *ACS* 2011 and ACS 2019, by US Census Bureau.

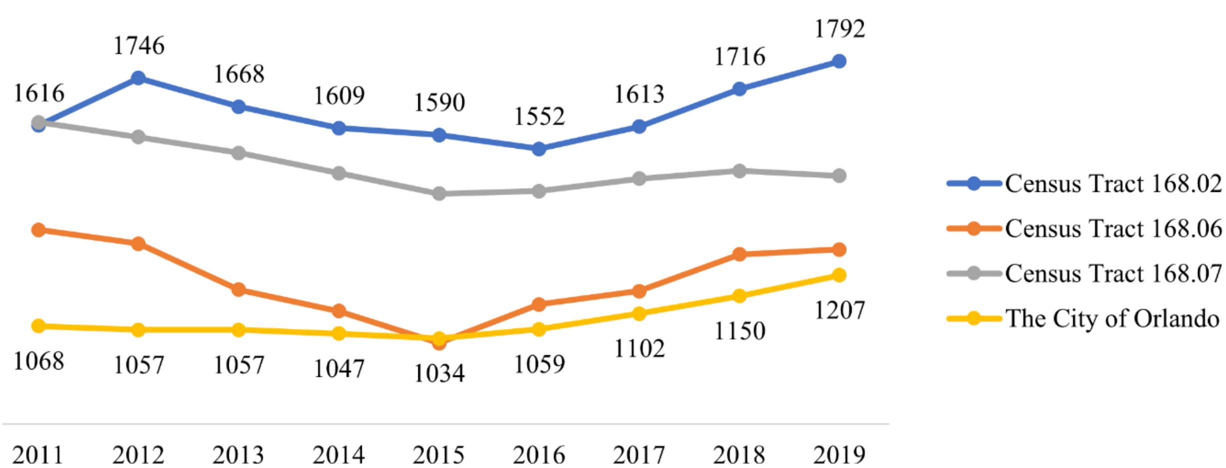
While annual median household incomes for the city of Orlando, including the Lake Nona region, have steadily increased holistically, the core of the Lake Nona region—census tract 168.02—has shown a substantially higher median household income ($96,205 USD) than its adjacent census tracts and roughly double that of Orlando ($51,757 USD). Findings suggest the disproportionately higher incomes strongly correlate with census tract 168.02's proximity to an above-average number of technology-focused industries and medical institutions in the Lake Nona Medical City.

2. Housing Cost

As Lake Nona's supply of higher-income buyers or renters rose, so did the demand for more expensive housing. **Figure 6-8** below details this phenomenon: from 2011 to 2019, the monthly cost of housing in census tract 168.02 remained nearly 50% higher than the city of Orlando's and well above that of the adjacent census tracts. Median monthly housing costs for census tract 168.02 ($1,653 USD), the city of Orlando ($1,110 USD), and the State of Florida ($1,503 USD) further illustrate the observed disparity between the study area and the overall state (US Census Bureau, 2015-2019).

Chart 6-8

Monthly Housing Cost for the Study Area and Orlando, 2011 to 2019



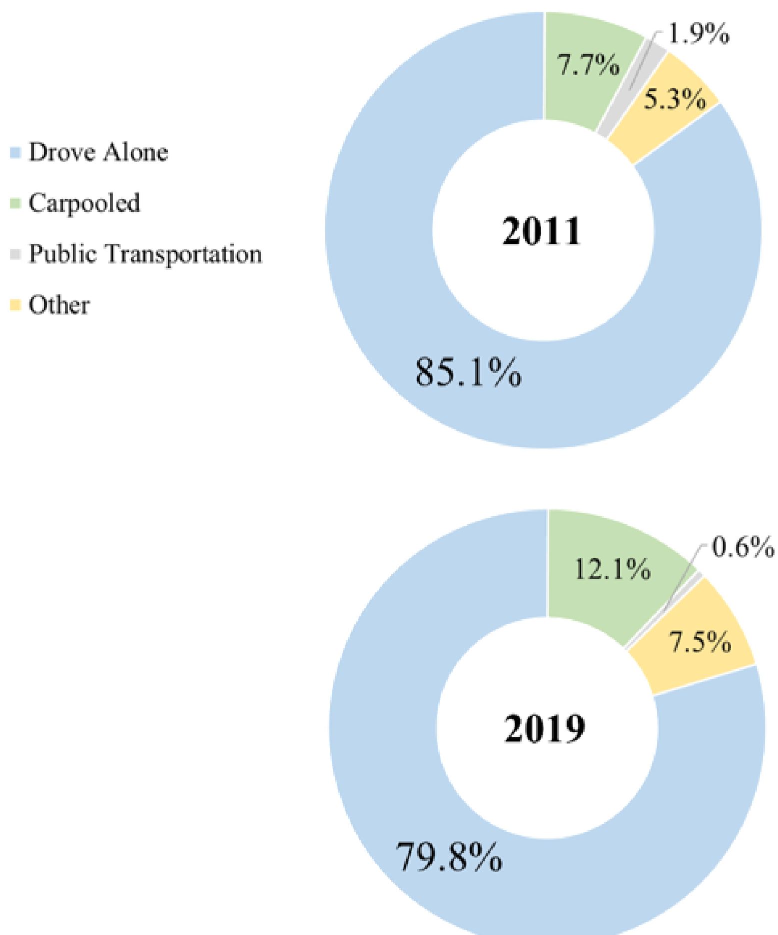
Note. Data retrieved from *ACS*, 2011–2019, by US Census Bureau.

5. *Transportation and Commute Mode*

Figure 6-9 below compares the commute modes of Lake Nona residents in 2011 and in 2019. Single-occupancy trips, represented as "Drove Alone" in the figure, constituted most of the travel to and from employment locations in the Lake Nona region, with 85.1% in 2011 and 79.8% in 2019. In contrast, only 1.9% of residents utilized public transportation/transit in 2011, and only an abysmal 0.6% used it in 2019. The implications of low public transit usage may pose an above-average risk or challenge to resident mode shift and establishing AV shuttle prevalence.

Figure 6-9

Commute Mode for the Study Area, 2011 and 2019

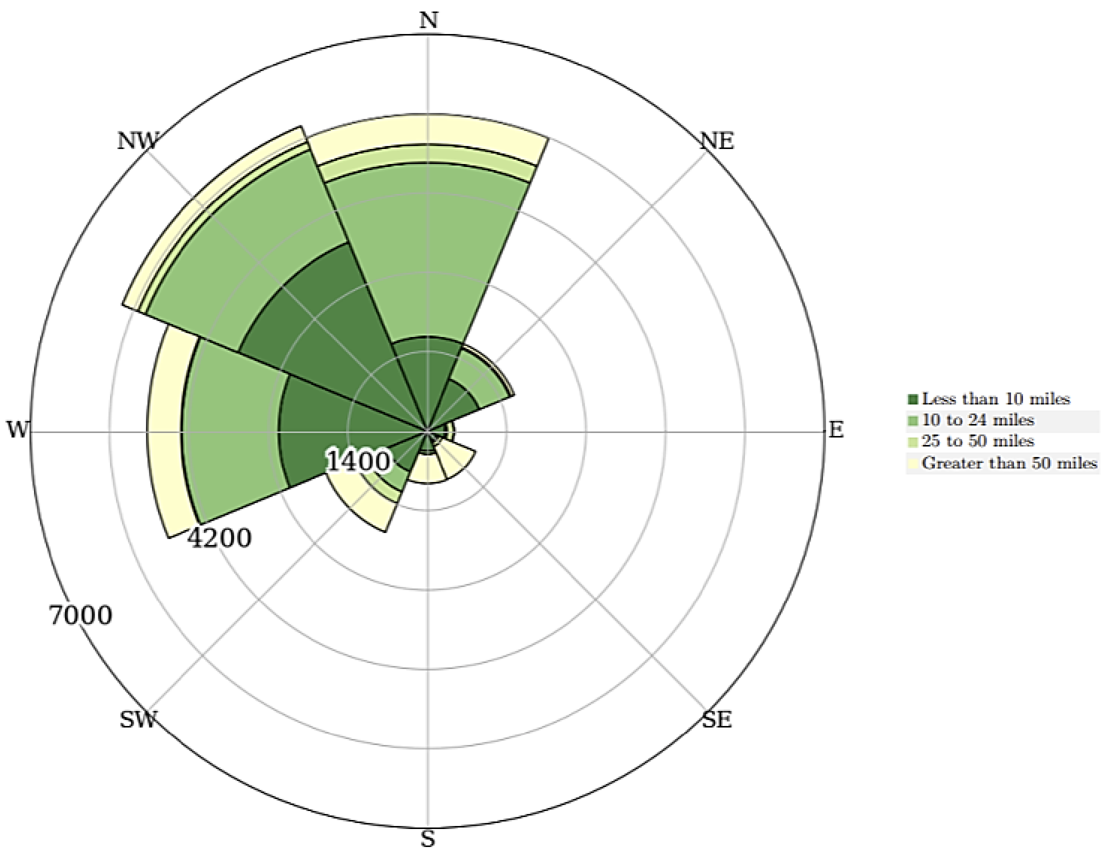


Note: Data retrieved from ACS 2011 and ACS 2019 (US Census Bureau).

In addition to the referenced travel patterns, **Figure 6-10** and **Figure 6-11** below reveal a potential source for the high share of single-occupancy travel. Most residents living in Lake Nona are employed outside the community, with commute distances ranging from less than 10 miles to greater than 50. Among them, 47.2 percent drove up to 10 miles to work. On the other hand, only 1,428 Lake Nona residents work locally.

Figure 6-10

Distance and Direction from Lake Nona to Work, 2019



Private Primary Jobs for All Workers in 2019

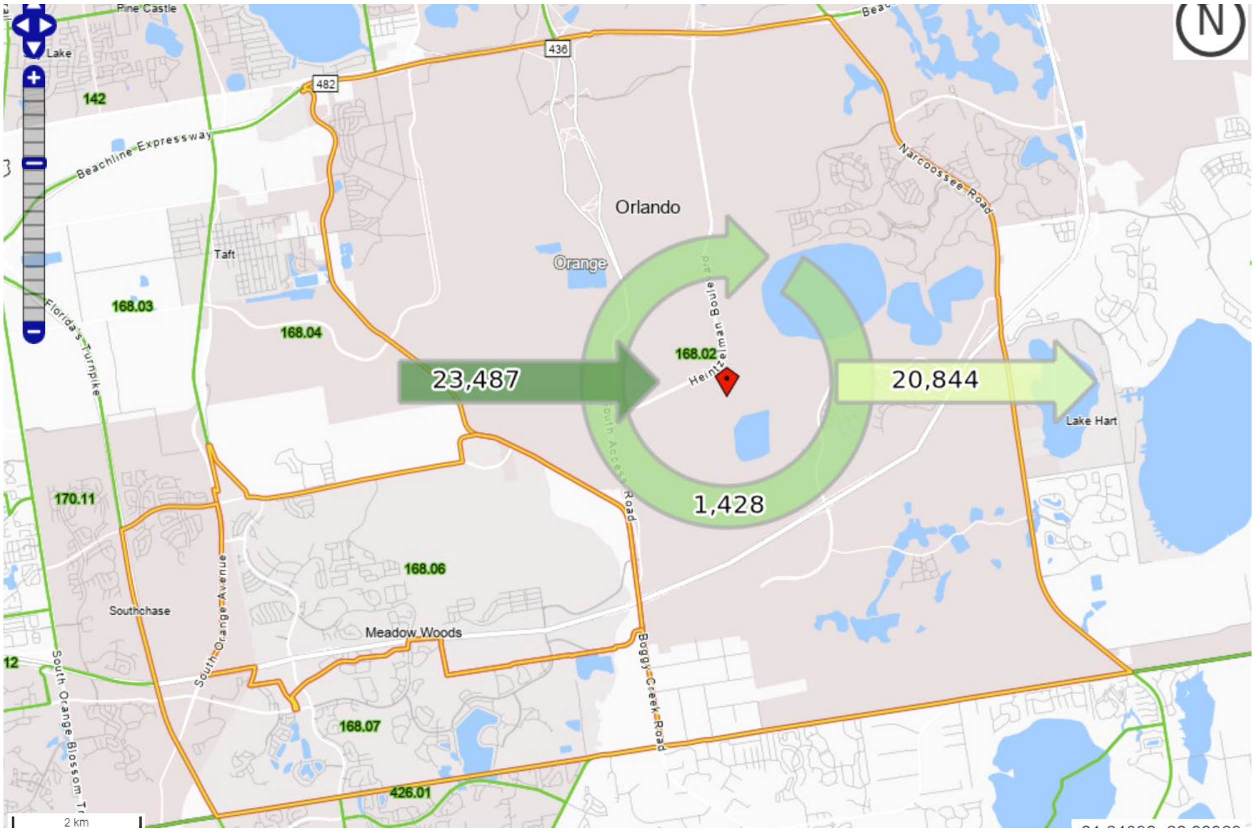
Distance from Home Census Block to Work Census Block, Living in Selection Area

Distance	2019 Count	2019 Share
Total Private Primary Jobs	22,272	100.0
Less than 10 miles	10,517	47.2
10 to 24 miles	7,646	34.3
25 to 50 miles	915	4.1
Greater than 50 miles	3,194	14.3

Note. From *OneTheMap,* 2019, by the US Census Bureau. (https://onthemap.ces.census.gov/).

Figure 6-11

Work Inflow and Outflow of Lake Nona, 2019



Note. From *OneTheMap,* 2019, by the US Census Bureau. (https://onthemap.ces.census.gov/).

It should be noted that this peripheral data is, to some extent, counterintuitive to the socioeconomic and housing observations made in section 6.4 regarding Lake Nona's proximity to Lake Nona Medical City and technology-oriented employment, which might lead to high ratio of local hiring and remote working.

Chapter 7. Move Nona Survey Analysis

1. Overview

In previous chapters, the research team introduced the AVEE Framework, the Move Nona AV shuttle program, and the community characteristics of Lake Nona, all in preparation to use Move Nona as a case study on how to customize and apply the AVEE Framework to evaluate and quantify the impact and effectiveness of an AV shuttle program.

Among all the criteria and sub-criteria presented in the AVEE Framework, a few critical ones need direct feedback and judgment of Lake Nona's residents and AV passengers to score, thus requiring a community survey. These criteria are:

1. Accessibility of an AV-based microtransit service (Element 3.1.1)
2. Measuring rider's perceptions of AVs' comfort level (Element 3.1.3)
3. Assessing the AV service's ability to attract repeat users (Element 5.1.2)
4. Estimating the AV service's reducing impact on driving (Element 5.1.3)
5. Collecting community opinions of the AV service's usefulness (Element 5.2.1)
6. Assessing the importance of the AV service as a neighborhood asset (Element 5.2.2)

Besides measuring the items above, the community survey can reveal why people in Lake Nona chose to use AV shuttles, or why they did not. Additionally, the background information and perception questions can help profile existing and potential AV riders. The outcome can usher future investors or government officials to understand customers' preferences and needs, helping to identify strategies that will promote AV-based microtransit programs.

The organization of this chapter is as follows: sections 7.2 and 7.3 illustrate how the research team designed, distributed, and validated the survey. Sections 7.4, 7.5, and 7.6 present the demographic and transportation characteristics of the sample, the riders, and non-riders, and then analyze the factors determining AV shuttle usage. A summary of user experiences and examples in which survey outcomes are applied to the AVEE Framework are also included. Lastly, the research studies survey respondents' perceptions of AV shuttles, exposing latent determinants of accepting new technology and providing recommendations to enhance future ridership.

2. Survey Development

The research team designed an anonymous questionnaire survey, hereafter referred to as the Move Nona survey, to investigate the perceptions of the Move Nona AV shuttle service's community impact as held by people who live or work in Lake Nona. All participants were adults who signed a consent form to engage. The University of Florida's Institutional Review Board (IRB) reviewed, approved, and exempted the study on July 26, 2022 (ID: IRB202201461).

The survey also underwent a rigorous face- and content-validity assessment by subject-matter experts from the University of Florida, FDOT, Beep, and Tavistock Development Company to refine the wording, credibility, and clarity of survey drafts.

The Move Nona survey had two versions: the first was for people who have previously ridden in a Move Nona AV shuttle in Lake Nona (referred to as the "rider version," see **Appendix A**), and the second was for those who only observed an AV shuttle operating in the region but never took a ride before (referred to as the "non-rider version," see **Appendix B**).

Both versions consisted of three parts. To reduce the complexity, the first two parts of both versions contained the same questions, while each version's third part was distinct.

Part one of the surveys had 25 questions focusing on respondents' perceptions of the AV shuttle, using attitude statements as the question format. The purpose was to delve into respondents' latent constructs and views on AVs and to discover factors that might encourage or discourage ridership. The answer choices ranged across a five–point Likert scale (1—Strongly Disagree, 2—Disagree, 3—Neither Disagree nor Agree, 4—Agree, and 5—Strongly Agree). Note that the Likert scale is a universal, convenient method to collect, understand, and interpret survey data, usually using the mean and median of the answers to show a central tendency.

The six constructs of perceptions, extracted and modified from technology acceptance literature (i.e., survey-based research on people's willingness to accept new technology), were as follows (Chan & Lee, 2021; Mattia et al., 2022; Wang et al., 2018):

1. *Perceived ease of use* (questions 1.1–1.3). This construct evaluates the extent to which a consumer thinks using a new product or technology (an AV shuttle, in this case) is easy.
2. *Perceived usefulness* (questions 1.4–1.6). This construct evaluates the extent to which a consumer believes an AV shuttle is useful in achieving goals (e.g., reducing travel time or enhancing convenience).
3. *Intention to use* (questions 1.7–1.9). For previous/current riders, this construct indicates their willingness to continue using an AV shuttle. For non-riders, it measures their inclination to use one someday.
4. *Safety concerns* (questions 1.10–1.16). This construct evaluates people's concerns about safety and risks when deciding to ride in or share the road with an AV, reflecting their perceptions of AV's reliability.
5. *Neighborhood asset* (questions 1.17–1.19). This construct evaluates whether the residents think an AV shuttle system is or would be a valuable asset to the neighborhood.
6. *Personal innovativeness* (questions 1.20 – 1.22). This construct evaluates the degree to which a person tends to adopt new technologies/services readily, as compared to others.
7. *Environmental awareness* (questions 1.23–1.25). This construct studies a person's understanding of environmental issues like carbon emissions and resource wastefulness, as well as their tendency to choose more sustainable travel modes.

Part two of both surveys comprised multiple-choice questions that gathered information on the respondents' demographic characteristics and expectations of future AV services. The first nine questions (2.1–2.9) asked about their gender, age, race/ethnicity, educational attainment, current employment status, annual household income, and travel habits. The following four questions were about residents' present and desired travel distances to an AV stop, their maximum tolerable waiting times, and features/services that would improve usage.

Part three included different questions for the non-rider and rider survey versions. For the non-rider version, there was a single multiple-choice question about the reasons for not using an AV shuttle. In contrast, the rider version had five multiple-choice questions (3.1–3.5) about riding frequency, purpose, and motivations, plus 11 attitude statement questions on riders' experiences and satisfaction.

3. Survey Deployment

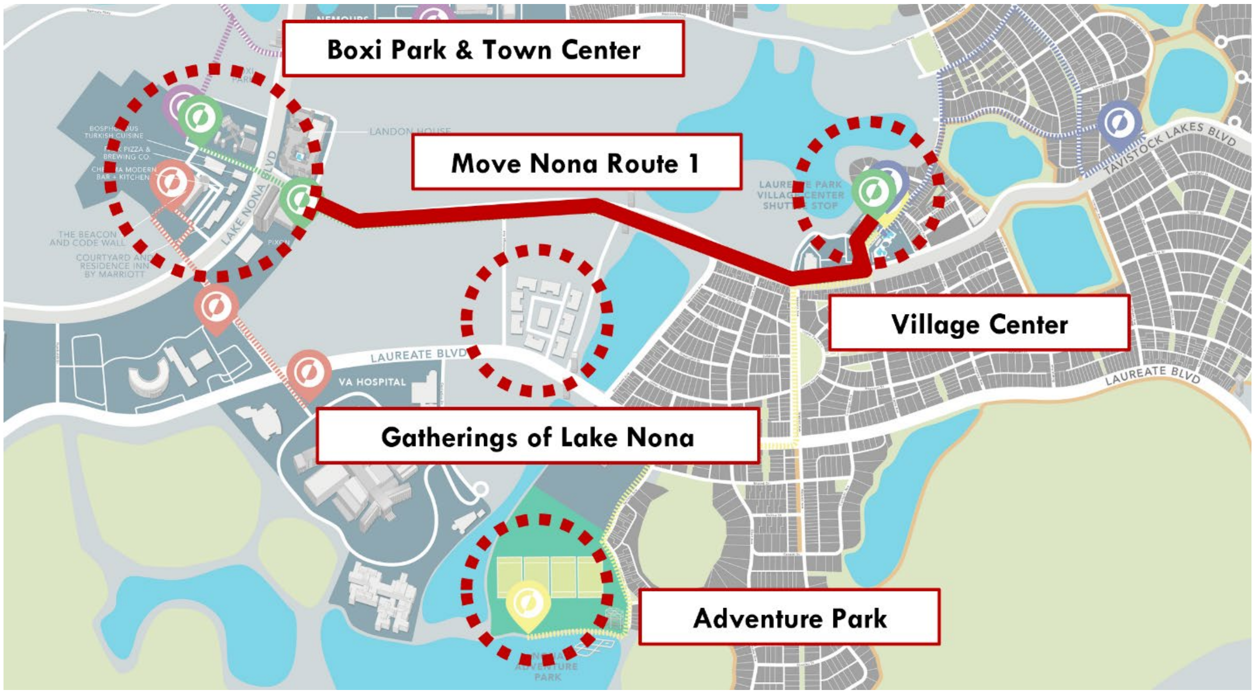
The University of Florida research team employed two distribution methods for the Move Nona survey: onsite and online. Valid responses collected from each method were 109 and 114, with a sum of 223 (n = 223). The deployment period was between July 29 and September 23, 2022.

1. Onsite Survey

The onsite survey included a four-page printed questionnaire administered over two distribution periods. The first period was from July 29 to July 31, 2022, between the hours of 9 a.m. to 9 p.m. The team asked randomly selected participants around Lake Nona and on the AV shuttles to complete the survey. The team collected 80 valid responses (15 from day one, 35 from day two, and 30 from day 3). **Figure 7-1** highlights the public sites used to reach out to the locals: the Boxi Park/Town Center, Village Center (the Laureate Park), the Adventure Park, the Gatherings of Lake Nona (a senior living condominium), and the Move Nona Route 1.

Figure 7-1

Locations of the Research Team Distributing the Printed Survey, Period 1



Note. Map courtesy of Beep. (https://rideBeep.com/location/move-nona/)

The second period was from July 29 to August 31, 2022. To avoid soliciting, the team asked Lake Nona residents to continue distributing printed copies through snowball/chain-referral sampling to the rest of the neighborhood's private residential areas. In the end, there were 29 valid (completed) responses.

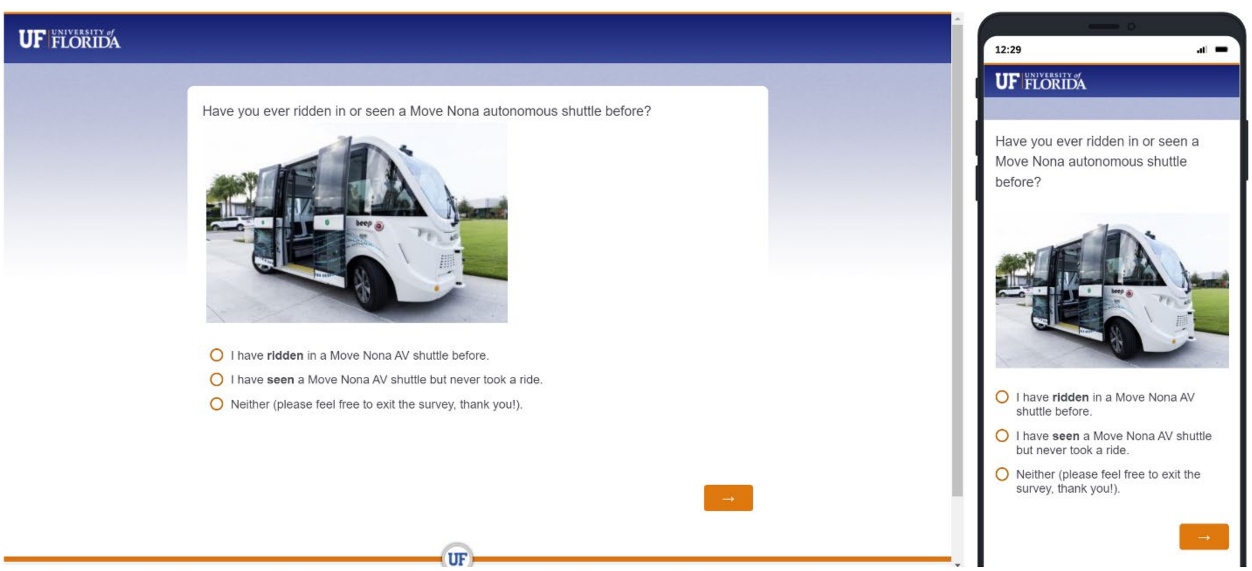
2. Online Survey

The University of Florida team administered the online surveys through Qualtrics Survey, which contained rider and non-rider versions identical to the printed ones. The survey was active and distributed via the Lake Nona homeowner's mailing list from Tuesday, August 23, to Friday, September 23, 2022.

The online platform received 150 responses during the deployment period. After verifying the completeness of all answers and using the Qualtrics platform to validate that all IP locations fell within the Lake Nona region, there remained 114 valid responses (n = 114). **Figure 6-2** below is a demo of the online and mobile interfaces of the survey, showing the opening page.

Figure 7-2

Online and Mobile Interfaces of the Move Nona Survey



Note. Screenshots from the online survey when optimized for a webpage and for a smartphone. The platform used is *Qualtrics Survey.* Own work.

4. Profile of the Respondents

This section outlines the demographic characteristics and travel modes of the respondents and tests whether the survey sample is a statistically accurate representation of the Lake Nona population (using the chi-square goodness of fit test).

1. Demographic Characteristics of the Sample

Table 7-1 below summarizes the demographic information of the respondents (n = 223). 53.36 percent were female, and 61 percent were between 35 and 54 years old. A predominant share of respondents was White (55.16 percent). The respondents were well educated: 43.95 percent had a bachelor's degree, and 31.39 percent had a master's degree or higher. 43.05 percent of households earned over $150,000 USD per year; 26.45 percent of the respondents chose not to report. In addition, 128 respondents (57.40 percent) have ridden in a Move Nona AV shuttle before, while 95 (42.60 percent) have seen one but have not used it yet.

Table 7-1

Demographic Profile of the Respondents (n = 223)

Item (Question # in the survey)	Frequency	Percentage (%)
AV shuttle-riding experience		
1. Yes (used before)	128	57.40
2. No (saw before)	95	42.60
Gender (2.1)		
1. Male	96	43.05
2. Female	119	53.36
3. Other/prefer not to answer	8	3.59
Age (2.2)		
1. 18–24	21	9.42
2. 25–34	37	16.59
3. 35–44	78	34.98
4. 45–54	59	26.46
5. 55–64	20	8.97
6. 65–74	8	3.59
7. 75 and over	0	0
Race/ethnicity (2.3)		
1. Asian/Pacific Islander	29	13.00
2. Black/African American	10	4.48
3. White	123	55.16
4. Hispanic	48	21.52
5. Other/prefer not to answer	13	5.83

Educational attainment (2.4)			
1.	Below high school	2	0.90
2.	High school graduate/GED	11	4.93
3.	Some college, no degree	22	9.87
4.	Associate degree	14	6.28
5.	Bachelor's degree	98	43.95
6.	Master's degree or higher	70	31.39
7.	Other/prefer not to answer	6	2.69
Employment status (2.5)			
1.	Work part-time	24	10.76
2.	Work full-time	138	61.88
3.	Self-employed	24	10.76
4.	Not employed	4	1.79
5.	Retired	18	8.07
6.	Full-time student	7	3.14
7.	Other/prefer not to answer	8	3.59
Annual household income (USD) (2.6)			
1.	Under $25,000	5	2.24
2.	$25,000–$49,999	12	5.38
3.	$50,000–$74,999	12	5.38
4.	$75,000–$99,999	14	6.28
5.	$100,000–$149,999	25	11.2
6.	$150,000 or more	96	43.05
7.	Other/ Prefer not to answer	59	26.45

Note. Data collected from the Move Nona survey.

2. Testing the Sample's Representation of the Lake Nona Population

To examine whether the Move Nona survey sample represented the Lake Nona population well, the team needed to compare the distribution of some key demographic features, e.g., gender, age group, and income level. This scenario matched the condition to apply the chi-square goodness of fit test, which is widely used to compare a randomly selected sample of a single, categorical variable to the wider population from where it was derived and is thus a good way to find out if sample data follows its population distribution (Frimodig, 2020; Frost, J., 2022). The testing software was the JMP. The American Community Survey (ACS) provided the data for this population (Lake Nona residents).

1. Gender

A chi-square goodness of fit test was performed to determine if the sample's gender distribution was representative of Lake Nona's overall. As shown in **Figure 7-3**, the test compared the sample's female proportion, 55.34 percent, to the expected value of Lake Nona's female proportion, 51.42 percent, to identify if there was a significant difference (US Census Bureau, 2019). The result indicated that the gender ratio in the sample was not statistically different from the population. X^2 (1, N = 215) = 1.329, p = .249.

Figure 7-3

Testing Results of Gender Distribution

Frequencies

Level	Count	Prob
Female	119	0.55349
Male	96	0.44651
Total	215	1.00000
N Missing	5	
2 Levels		

Test Probabilities

Level	Estim Prob	Hypoth Prob
Female	0.55349	0.5142
Male	0.44651	0.4858

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	1.3319	1	0.2485
Pearson	1.3285	1	0.2491

Note. "Prob" is the observed probability, which is the sample's gender proportion in this test. The "Hypoth Prob" is the hypothetical probability/expected probability, which is the female proportion of Lake Nona in this test.

2. Race/Ethnicity

Three tests were performed to find whether the sample's racial group distribution accurately represented the wider racial distribution in Lake Nona. The tests compared the sample's proportions of White (including Hispanic), Black, and Asian populations to Lake Nona's to identify significant differences. **Figure 7-4** showed the data, and the result indicated no statistical differences. X^2 (1, N = 223) = 0.263, 0.545, 0.186, p > .05.

Figure 7-4

Testing Results of White, Asian, and Black Groups' Proportions

Test Probabilities

Level	Estim Prob	Hypoth Prob
Other	0.23318	0.203
White	0.76682	0.797

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	1.2128	1	0.2708
Pearson	1.2557	1	0.2625

Test Probabilities

Level	Estim Prob	Hypoth Prob
Asian	0.13004	0.117
Other	0.86996	0.883

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	0.3561	1	0.5507
Pearson	0.3673	1	0.5445

Test Probabilities

Level	Estim Prob	Hypoth Prob
Black	0.04484	0.067
Other	0.95516	0.933

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	1.9679	1	0.1607
Pearson	1.7513	1	0.1857

Note. From left to right were White, Asian, and African American groups.

3. Age Group

The third test was centered around age distribution. Multiple chi-square goodness-of-fit tests were performed to determine whether the sample and the larger population's proportion of each age group were the same statistically. For example, the test could tell if there was a significant difference between the sample's proportion of age group 18–24 (9.42 percent) and Lake Nona population's share of the same age group (11.71 percent) (US Census Bureau, 2019). The result (**Figure 7-5**) indicated that, among the six age groups, the proportions of age groups 18–24, 25–34, 45–54, and 55–64 in the sample were not statistically different from that of the population. X^2 (1, N = 223) = 0.287, 0.070, 3.582, and 0.090, p > .05. S

Figure 7-5

Testing Results of Age Group's Distribution Comparisons (Part 1)

Test Probabilities

Level	Estim Prob	Hypoth Prob
18-24	0.09417	0.11711
Other	0.90583	0.88289

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	1.2065	1	0.2720
Pearson	1.1349	1	0.2867

Test Probabilities

Level	Estim Prob	Hypoth Prob
25-34	0.16592	0.21575
Other	0.83408	0.78425

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	3.4823	1	0.0620
Pearson	3.2726	1	0.0704

Test Probabilities

Level	Estim Prob	Hypoth Prob
45-54	0.26457	0.21271
Other	0.73543	0.78729

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	3.3944	1	0.0654
Pearson	3.5819	1	0.0584

Test Probabilities

Level	Estim Prob	Hypoth Prob
55-64	0.08969	0.12752
Other	0.91031	0.87248

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	3.1563	1	0.0756
Pearson	2.8690	1	0.0903

Note. The four age groups were not statistically different from the population.

However, the proportions of age groups 35–44 and 65–74 were statistically different, with a P-value less than 0.05. X^2 (1, N = 223) = 19.216 and 10.182, p < .01. The outcome (see **Figure 7-6**) meant that the ratio of people aged 65–74 who took the survey was too low, whereas people aged 35–44 were overrepresented. One reason for these differences was the voluntary sampling bias. The research team did not meet many older people in public spaces or inside the AVs. Also, the older ones might have been less likely to respond to the online survey (only two people over 65 submitted it). In comparison, the younger ones were more active. Moreover, several residents at the senior living condo (Gathering of Lake Nona) commented that they had never seen an AV coming to their place. The limited service area reduced the exposure of AV to this age group.

Nevertheless, since most age groups were representative of the population, the sample was worth adopting with reservation when drawing conclusions for community members over 65.

Figure 7-6

Testing Results of Age Group's Distribution Comparisons (Part 2)

Test Probabilities

Level	Estim Prob	Hypoth Prob
35-44	0.34978	0.22684
Other	0.65022	0.77316

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	17.3365	1	<.0001*
Pearson	19.2164	1	<.0001*

Test Probabilities

Level	Estim Prob	Hypoth Prob
65-74	0.03587	0.09997
Other	0.96413	0.90003

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	13.1837	1	0.0003*
Pearson	10.1820	1	0.0014*

Note. Age groups 35–44 and 65–74 had statically significant results (P-value in orange).

4. Income Level

The fourth test was to determine whether the sample and the wider population's income distribution were similar. The test compared the sample's proportion of households earning over $75,000 USD annually (60.54 percent) to Lake Nona's (57.0 percent) in order to identify significant differences (Tavistock Development Company, 2018). The team selected this income group to see if the sample had the proportionate amount of middle- and upper-middle-class families suggested by Tavistock Development Company's marketing materials, which set a benchmark of $75,000 USD or more (Tavistock Development Company, 2018). The result (**Figure 7-7**) indicated that the sample's proportion of such middle-class or above households was not statistically different from that in the population, X^2 (1, N = 223) = 1.139, p = .286.

Figure 7-7

Testing Results of Household Earning Over $75K USD Annually

Frequencies

Level	Count	Prob
Above 75K	135	0.60538
Other	88	0.39462
Total	223	1.00000
N Missing	5	
2 Levels		

Test Probabilities

Level	Estim Prob	Hypoth Prob
Above 75K	0.60538	0.57
Other	0.39462	0.43

Test	ChiSquare	DF	Prob>Chisq
Likelihood Ratio	1.1477	1	0.2840
Pearson	1.1390	1	0.2859

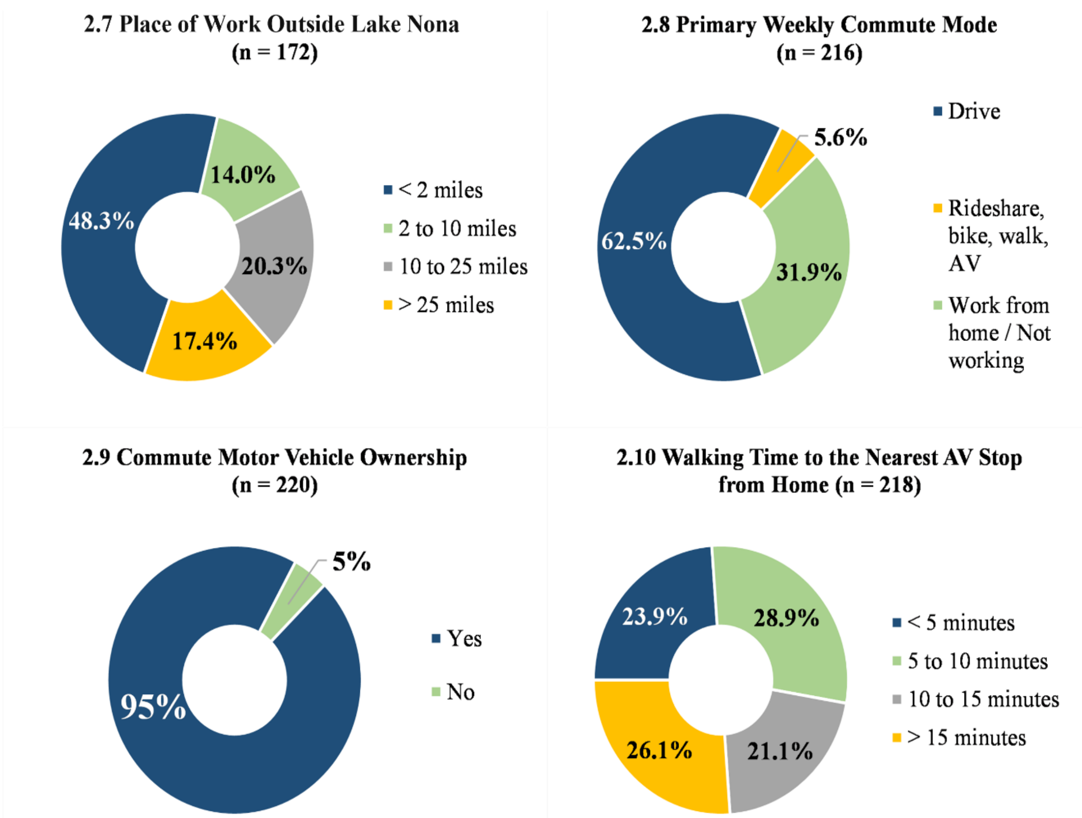
Note. Data is from *ACS* and *Tavistock Development Company*.

3. Commute Patterns and Mode Choices

Besides demographic data, questions 2.7–2.9 gathered the sample's travel patterns and commute mode choices, as represented in **Figure 7-8**. The results showed that the respondents had a high private motor vehicle ownership (95 percent). A relatively high share of the sample (31.9 percent) was either "work from home" or "not currently working," whereas 62.5 percent used personal automobiles for their commute. Only 5.6 percent traveled by bike, bus, or walking, which suggested a significant automobile dependency level that implied that AVs could not replace driving in the short term. On the other hand, 48.3 percent of the respondents worked less than two miles from Lake Nona, and 73.9 percent only needed to walk less than 15 minutes to get to the nearest AV stop, revealing a potential for the AV shuttle to attract more residents to use the service more frequently within the neighborhood and to reach nearby public or commercial destinations.

Figure 7-8

Travel and Commute Patterns of the Sample



Note. Data is from the Move Nona survey.

5. *Analysis of Riders*

1. Demographic Characteristics of the Riders

The survey result (shown in **Table 7-2** below) illustrated that among the 223 respondents, 128 (57.40 percent) have previously ridden in a Move Nona AV shuttle. Of that group, 53.90 percent were female, slightly more than the male proportion, at 43.75 percent. 62.5 percent of the riders were between 35 and 54, while only two passengers were older than 65. A significant number of respondents were White (55.47 percent) and employed full time (63.28 percent). The riders also possessed a high education level: 46.09 percent had a bachelor's degree and 28.91 percent had a master's degree or above. 42.19 percent of the respondents reported a household income of $150,000 USD per year, followed by 10.94 percent reporting a household income between $100,000 and $150,000 USD per year.

Table 7-2

Demographic Profile of the Riders (n = 128)

Item (Question # in the survey)		Frequency	Percentage (%)
Gender (2.1)			
1.	Male	56	43.75
2.	Female	69	53.90
3.	Other/Prefer not to answer	3	2.34
Age (2.2)			
1.	18–24	11	8.59
2.	25–34	20	15.63
3.	35–44	49	38.28
4.	45–54	31	24.22
5.	55–64	15	11.72
6.	65–74	2	1.56
7.	75 and over	0	0
Race/ethnicity (2.3)			
1.	Asian/Pacific Islander	17	13.28
2.	Black/African American	6	4.69
3.	White	71	55.47
4.	Hispanic	25	19.53
5.	Other/prefer not to answer	9	7.03
Educational attainment (2.4)			
1.	Below high school	2	1.56
2.	High school graduate/GED	7	5.47
3.	Some college, no degree	11	8.59
4.	Associate degree	9	7.03
5.	Bachelor's degree	59	46.09
6.	Master's degree or higher	37	28.91
7.	Other/prefer not to answer	3	2.34

Employment status (2.5)			
1.	Work part-time	14	10.93
2.	Work full-time	81	63.28
3.	Self-employed	14	10.93
4.	Not employed	1	0.78
5.	Retired	9	7.03
6.	Full-time student	5	3.91
7.	Other/prefer not to answer	4	3.13
Annual household income (USD) (2.6)			
2.	Under $25,000	3	2.34
3.	$25,000–$49,999	5	3.91
4.	$50,000–$74,999	9	7.03
5.	$75,000–$99,999	7	5.47
6.	$100,000–$149,999	14	10.94
7.	$150,000 or more	54	42.19
8.	Other/prefer not to answer	36	28.13

Note. Data from the Move Nona survey.

2. Travel Patterns and Reasons for Using the AV Shuttle

Even though Move Nona was a demonstration project rather than a formal public transportation program, it was still crucial to learn how and why people used it. Questions 3.1–3.4 of the rider survey asked the respondents about their patterns of AV shuttle use (**Table 7-3**). Question 3.5 asked for reasons for choosing this new travel mode (listed in **Figure 7-9** in descending order).

Table 7-3

Move Nona AV Shuttle Rider Travel Patterns (n = 128)

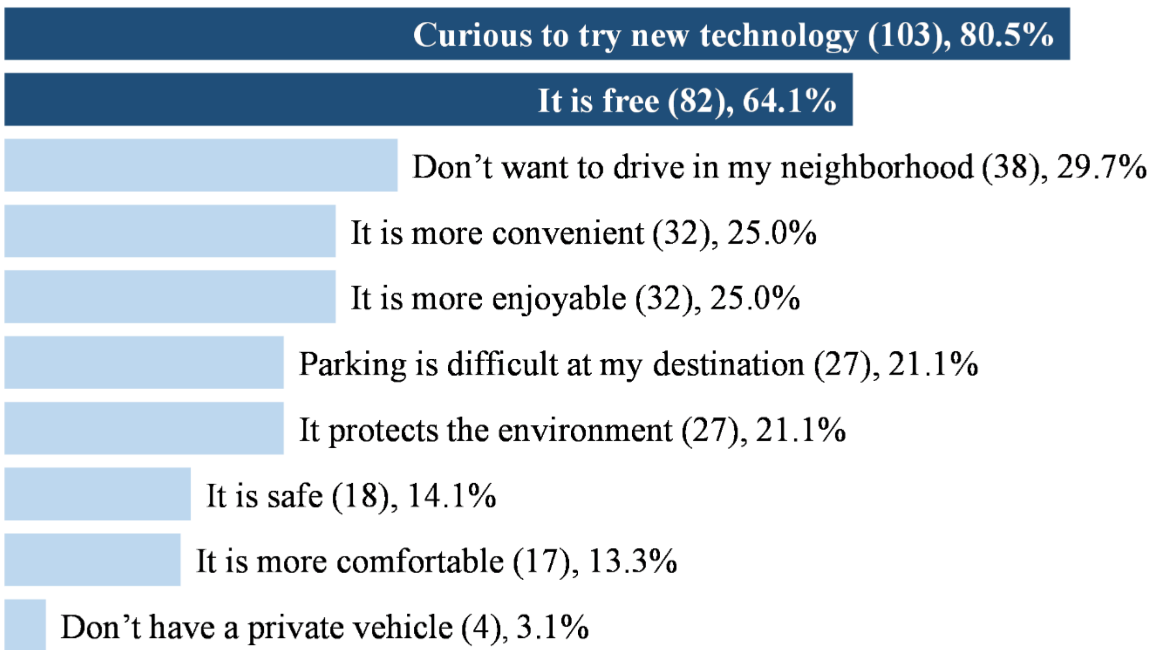
Question in the survey		Frequency	Percentage (%)
3.1 How many times have you ridden in a Move Nona shuttle in the past year?			
1.	More than 20 times	2	1.56
2.	10 to 20 times	10	7.81
3.	3 to 10 times	46	35.94
4.	Less than 3 times	68	53.13
5.	No answer	2	1.56
3.2 How often did you ride the Move Nona AV shuttle on average in the past year?			
1.	At least once per week	2	1.56
2.	At least once per month	23	17.97
3.	Less than once per month	99	77.34
4.	No answer	4	3.13
3.3 Do you have a fixed routine or schedule when riding the Move Nona AV shuttle?			
1.	Yes	15	11.72
2.	No	112	87.50
3.	No answer	1	0.78

3.4 What was your primary destination when using the Move Nona AV shuttle?			
1.	Work	3	2.34
2.	Leisure (dining out, shopping, etc.)	102	79.69
3.	Commute connection	3	2.34
4.	No specific destination	20	15.63

Note: Data is from the Move Nona survey.

Figure 7-9

Rider Reasons for Using the Move Nona AV Shuttle (n = 128)



Note. We used a multiple-answer question (3.5) here, which yielded 380 answers from 128 responses. The percentage indicated how many respondents selected a particular choice.

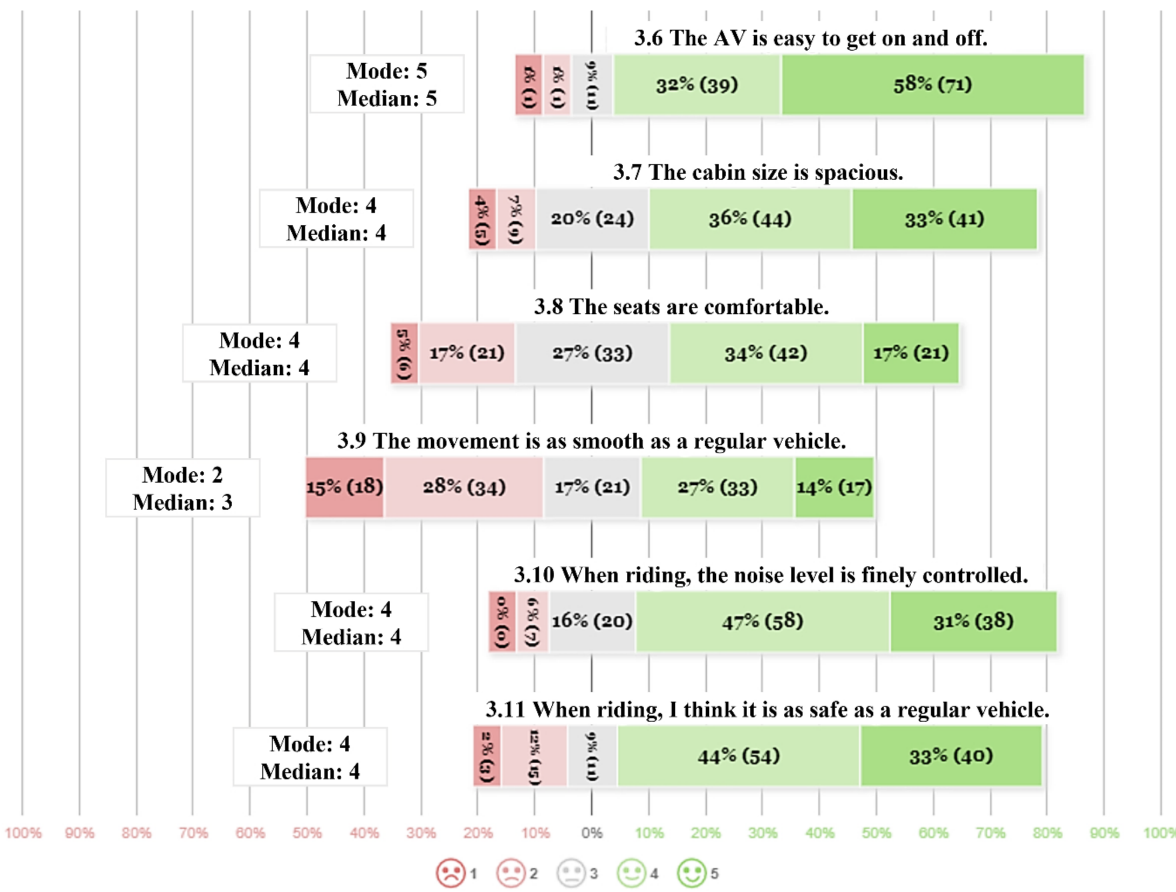
The results revealed that almost no one in the study area was using the Move Nona AV shuttle as a primary means of transportation. About 80 percent of respondents used it for leisure and 16 percent rode it because of curiosity. Moreover, 53.13 percent took less than three rides during the past year. 77.34 percent had a frequency of less than once per month. Regarding the reasons for trying the shuttle service, 103 of the 128 respondents (80.5 percent) were motivated to try new technology, and 82 (64.06 percent) tried it because it was free, matching the findings of question 3.4. Only one-quarter of the respondents were intrigued by the AV shuttle's performance, such as its convenience. Many riders just took a ride for fun or used it to show their guests around Lake Nona. Additionally, four respondents used the comment section for reasons not listed in the questionnaire, saying that they took AV shuttles to avoid driving after drinking alcohol. In short, people treated Move Nona as an alternative travel method for special occasions instead of a commute mode with a routine, which was consistent with the intent of the program.

3. User Experiences

Questions 3.6–3.11 focused on six aspects of the Move Nona AV shuttle rider feedback: ease of getting boarding and disembarking, cabin size, seat comfort level, movement stability, interior noise control, and safety. The questions adopted the format of attitude statements based on a 1–5 Likert scale ranging from "Strongly Disagree" (1) to "Strongly Agree" (5). **Figure 7-10** presents the results in a bar figure with mode and median calculated.

Figure 7-10

Move Nona Rider Feedback (n = 123)



Note. Data from the Move Nona survey.

In **Figure 7-10**, each bar represents a question. Positive answers are in green, and negative ones are in red. The position of a bar reflects respondents' attitudes toward a question, with rightward bars indicating a positive attitude, and leftward bars indicating a negative attitude.

The figure displayed that most passengers were satisfied with the ease of boarding and disembarking the Move Nona AV (question 3.6, for example, had a mode and median of 5), suggesting the shuttle door size and step height were appropriate. 80 percent of passengers provided positive answers that generally agreed that the cabin size, noise level, and safety standards were acceptable when taking a ride. (Questions 3.10 and 3.11 both had modes and medians of 4). In contrast, although the mode of question 3.8, which interrogated seat comfort level, reached 4, the median was between 3 and 4, and 49 percent of the respondents felt that the seats were not comfortable enough. The issue might attribute to Navya, the manufacturing group that used European seat sizes and standards without localization for US customers. AV operators from Beep also pointed out this issue according to the passenger feedback they received.

Moreover, the results highlighted a salient problem of the AV shuttle: its "smoothness" of movement. Unexpected braking substantially impaired riders' experiences, willingness to ride again, and desire to recommend the AV to a friend. For instance, AVs that relied on lidar can distracted by fast-growing foliage during the summer, leading to seasonally excessive braking. This phenomenon was highly unfriendly to users, especially the elderly. With a mode of 2 and a median of 3, question 3.8's result proved that 43 percent of riders found the AV's movement unpleasant, and some respondents used comment spaces to reiterate their worries.

4. Measuring Comfort Score

The AVEE Framework's Element 3.1.1 of Pillar 3 (Service and Management) mentioned that assessing an AV shuttle's comfort level required a survey to measure the convenience of door access, interior space, smoothness of the ride, seat size, and noise. These variables were covered in questions 3.6–3.10 of the rider version. Since each question had a median and a mode, we assigned scores from 1 to 5 to match those two outcomes, thus gathering 10 scores for the five questions. By adding the scores and taking the average, the final score for Element 3.1.3 was 3.9.

6. *Analysis of Non-Riders*

1. Demographic Characteristics of the Non-Riders

As shown in **Table 7-4** below, 95 respondents have seen a Move Nona AV shuttle but have never ridden in one. Demographic features of the non-rider group revealed similar patterns as those in the overall sample and in the rider group. 52.63 percent of the non-riders were female, 54.74 percent were White (this rose to 80 percent after including White Hispanics), and 60 percent were between 35 and 54. Compared to the rider group, the ratio of non-riders of color was close, yet the share of the elderly (over 65) was slightly larger, at 6.32 percent. As earlier, the group's education level was relatively high, with 34.74 percent of non-riders having graduated from college and 41.05 percent having earned graduate degrees or above. Regarding financial and employment status, 72.63 percent of non-riders worked full time or were self-employed. 44.21 percent reported annual household incomes of over $150,000 USD, and 11.58% reported household incomes between $100,000 and $150,000 USD.

Table 7-4

Demographic Profile of the Non-Riders (n = 95)

Item (Question # in the survey)	Frequency	Percentage (%)
Gender (2.1)		
1. Male	40	42.11
2. Female	50	52.63
3. Other/prefer not to answer	5	5.26
Age (2.2)		
1. 18–24	10	10.53
2. 25–34	17	17.89
3. 35–44	29	30.53
4. 45–54	28	29.47
5. 55–64	5	5.26
6. 65–74	6	6.32
7. 75 and over	0	0
Race/ethnicity (2.3)		
1. Asian/Pacific Islander	12	12.63
2. Black/African American	4	4.21
3. White	52	54.74
4. Hispanic	23	24.21
5. Other/prefer not to answer	4	4.21
Educational attainment (2.4)		
1. Below high school	0	0
2. High school graduate/GED	4	4.21
3. Some college, no degree	11	11.58

4.	Associate degree	5	5.26
5.	Bachelor’s degree	33	34.74
6.	Master’s degree or higher	39	41.05
7.	Other/prefer not to answer	3	3.16
Employment status (2.5)			
1.	Work part-time	10	10.53
2.	Work full-time	57	60.00
3.	Self-employed	12	12.63
4.	Not employed	3	3.16
5.	Retired	9	9.47
6.	Full-time student	4	4.21
7.	Other/prefer not to answer	4	4.21
Annual household income (USD) (2.6)			
1.	Under $25,000	2	2.11
2.	$25,000–$49,999	7	7.37
3.	$50,000–$74,999	3	3.16
4.	$75,000–$99,999	7	7.37
5.	$100,000–$149,999	11	11.58
6.	$150,000 or more	42	44.21
7.	Other/prefer not to answer	23	24.21

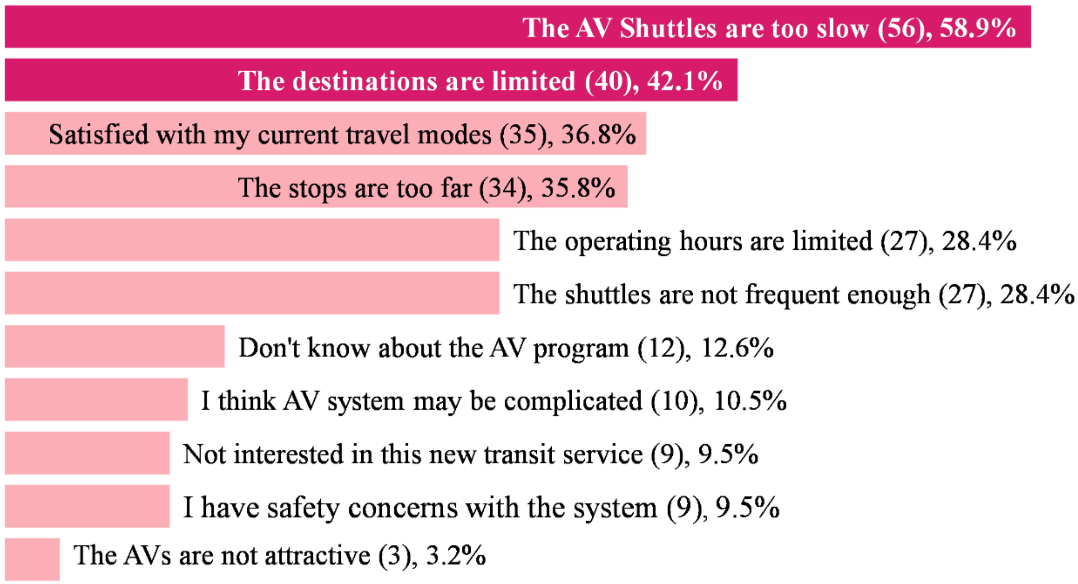
2. Reasons for Not Using the AV Shuttle Service

Part three of the survey’s non-rider version sought to uncover the reasons preventing non-riders from using or experiencing the Move Nona AV shuttle service. To do this, the version used multiple-answer question 3.1, in which the research team provided 11 possible choices proposed by the team members, stakeholders, and subject-matter experts.

Figure 7-11 listed the respondents’ choices in descending order. According to the figure, the top two factors that determined whether people would use Move Nona were “speed concerns” and “service areas.” Specifically, almost 60 percent of respondents were unsatisfied with its current low speed (**Figure 7-12**). 42.1 percent stated that the AV shuttles were not serving their desired destinations (for instance, a school, an office, or a grocery store). 35.8 percent pointed out that the AV stops were too far from their homes, and 28.4 percent thought the operating hours and shuttle frequency were limited. The rest of the answers were not as salient as the previous ones, citing minor safety concerns. Furthermore, since only three respondents claimed that the AVs were not attractive, one could infer that the design of the AVs were generally popular. Some residents mentioned in the comment section that they had not heard much about the service and that lacking the details about the service’s routes and pricing stopped them from taking a ride.

Figure 7-11

Reasons for Not Using the AV Shuttle Service (n =95)



Note. We used a multiple-answer question (3.5) to obtain the result. 95 respondents provided 262 answers. The percentage indicated how many respondents selected a particular choice.

Figure 7-12

Move Nona's Low-Speed Issue

Note. In two-way lanes, low operating speeds (12.5 mph) meant Move Nona shuttles would often block the road, irritating car drivers behind them. From *Autonomous shuttle service launches in Orlando* [Photograph], by E. Davis, 2019, (https://www.thejaxsonmag.com/article/autonomous-shuttle-service-launches-in-orlando/).

7. *Perceptions of the AV Shuttle*

Table 7-5 below quantifies all respondents' perceptions of the Move Nona AV shuttle by analyzing the seven latent constructs related to one's willingness to accept a new technology or product. The constructs and their relevant questions are: (1) perceived ease of use (questions 1.1–1.3); (2) perceived usefulness (questions 1.4–1.6); (3) intention to use an AV (questions 1.7–1.9); (4) safety concerns (questions 1.10–1.16); (5) perceived importance in choosing where to live (questions 1.17–1.19); (6) personal innovativeness (questions 1.20–1.22); and (7) environmental awareness (questions 1.20– 1.25). Inspecting the latent constructs can help researchers to profile a community and potential users more insightfully and to understand factors that might impact user travel behavior and choices, expediting the future promotion of similar AV-based microtransit services. The format of each question is a multiple-choice attitude statement. Respondents used a five-point Likert scale to answer the questions.

Table 7-5

Public Opinion Regarding the AV Shuttle

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Perceived ease of use:					
1.1 If I want to use the AV shuttle, I think it will be easy for me (Even if I haven't used it before).	11 (4.93%)	27 (12.11%)	26 (11.66%)	**71 (31.84%)**	*88 (39.46%)*
1.2 If I want to use the AV shuttle, it will not require a lot of mental effort (even if I haven't used it before).	9 (4.04)	29 (13.00)	11 (4.93)	**76 (34.08)**	*98 (43.95)*
1.3 If I want to use the AV shuttle, my interaction with it will be straightforward and understandable.	5 (2.24)	22 (9.87)	24 (10.76)	**76 (34.08)**	*96 (43.05)*
Perceived usefulness:					
1.4 I think the AV shuttle can let me get to my destination faster (if within its service area).	*88 (39.46)*	**57 (25.56)**	32 (14.35)	25 (11.21)	21 (9.42)
1.5 I think using the AV shuttle can let me get around easier (if within its service area).	41 (18.39)	50 (22.42)	**37 (16.59)**	*59 (26.46)*	36 (16.14)
1.6 I think the AV shuttle is a useful transportation method (if within its service area).	33 (14.80)	22 (9.87)	29 (13.00)	***70 (31.39)***	69 (30.94)
Intention to use:					
1.7 I have used/have planned to use the AV shuttle.	26 (11.66)	21 (9.42)	34 (15.25)	**61 (27.35)**	*81 (36.32)*

1.8 If the AV shuttle can reach my destination, I think I will use it.	19 (8.52)	31 (13.90)	20 (8.97)	**73** **(32.74)**	*80* *(35.87)*
1.9 If the AV shuttle can reach my destination, it can encourage me to travel more frequently.	30 (13.45)	35 (15.70)	**47** **(21.08)**	55 (24.66)	*56* *(25.11)*
Safety concerns:					
1.10 As a driver, I think driving near an AV shuttle is safe.	28 (12.56)	42 (18.83)	12 (5.38)	**60** **(26.91)**	*81* *(36.32)*
1.11 I think walking or riding a bike near an AV shuttle is safe.	18 (8.07)	19 (8.52)	19 (8.52)	**83** **(37.22)**	*84* *(37.67)*
1.12 I am comfortable with my children (age 12 - 18) using AV shuttles (if the service provider allows).	22 (9.87)	13 (5.83)	33 (14.80)	**64** **(28.70)**	*86* *(38.57)*
1.13 If the AV shuttle's speed increased from 15 mph (now) to 30 mph, I think walking/biking near it would be safe.	8 (3.59)	22 (9.87)	33 (14.80)	**70** **(31.39)**	*91* *(40.81)*
1.14 I think riding in an AV shuttle is not safe in windy or rainy weather.	46 (20.63)	59 (26.46)	***69*** ***(30.94)***	30 (13.45)	19 (8.52)
1.15 I think the AV shuttles may not perform well and cause problems to my trips in windy or rainy weather.	38 (17.04)	51 (22.87)	***74*** ***(33.18)***	41 (18.39)	19 (8.52)
1.16 If I must travel in windy or rainy weather, I cannot rely on AV shuttles.	29 (13.00)	60 (26.91)	***62*** ***(27.80)***	44 (19.73)	28 (12.56)
Importance in choosing home:					
1.17 I think having an AV shuttle service can make a neighborhood more attractive.	7 (7.37)	7 (7.37)	10 (10.53)	***40*** ***(42.1)***	31 (32.63)
1.18 If I wanted to choose where to live in the future, having an AV shuttle service would positively influence my decision.	15 (15.79)	16 (16.84)	**18** **(18.95)**	*27* *(28.42)*	19 (20)
1.19 The Move Nona AV service was a factor that I decided to live in Lake Nona.	*44* *(46.32)*	**22** **(23.16)**	21 (22.11)	7 (7.37)	1 (1.05%)
Personal innovativeness:					
1.20 In general, I like to try new technology/products.	1 (0.45)	1 (0.45)	25 (11.21)	**85** **(38.12)**	*111* *(49.78)*
1.21 If I hear about a new technology/product, I want to try it.	2 (0.90)	3 (1.35)	35 (15.70)	**90** **(40.36)**	*93* *(41.70)*
1.22 I am usually the first to try out a new technology/product among my peers.	11 (4.93)	34 (15.25)	***81*** ***(36.32)***	51 (22.87)	46 (20.63)
Environmental awareness:					
1.23 I consider my actions' potential environmental impact when making many decisions.	13 (5.83)	17 (7.62)	44 (19.73)	***102*** ***(45.74)***	47 (21.08)
1.24 I am willing to take more environmentally friendly actions even if they are less convenient.	12 (5.38)	33 (14.80)	54 (24.22)	***88*** ***(39.46)***	36 (16.14)
1.25 I am concerned about issues like air pollution, waste of resources, and climate change.	11 (4.93)	44 (4.93)	20 (8.97)	**90** **(40.36)**	*91* *(40.81)*

Note. Data is from the Move Nona survey. Each answer's median is in bold; answer mode is italicized.

From **Table 7-5**, the results of the “perceived ease of use” cluster of constructs indicates that most respondents thought using the AV shuttle would be easy for them even if they had never used it before. Respondent confidence might attribute to the high education level of the residents, which can translate to high technological competence.

Regarding the “perceived usefulness” cluster of constructs, non-riders claimed that the AV shuttle was not convenient for them to get around Lake Nona while riders held the opposite opinion. These conflicting attitudes were due to a selection bias, as people who use something would be likelier to admit its usefulness. Additionally, riders and non-riders agreed that increasing the operating speed of AV shuttles and expanding the service area coverage could encourage usage.

From the safety perspective, most respondents believed that it was safe to walk, bicycle, or ride near an AV shuttle. Respondents kept the same opinion even when hypothetically increasing the speed of the AV shuttle from 15 to 30 mph. Around 80 percent of the respondents agreed or strongly agreed with a potential speed increase. Therefore, based on the positive attitudes, increasing the speed of the AV shuttle could attract more people to take it without creating further safety concerns.

Furthermore, most respondents retained a positive (or at least neutral) attitude toward using the AV shuttle even under rainy or windy weather conditions, suggesting they believe the system to be reliable. However, the Lake Nona region is unlikely to have severe weather conditions, and Beep would not operate the AV shuttles in the event of a hurricane. Instead, this perspective is useful primarily in the event that another service is launched in an area with more dynamic weather.

Lastly, most of the 223 respondents claimed that they were willing to try new technology and products, particularly when the new technology or product ameliorates environmental concerns. In other words, an advanced, green transportation method could attract a considerable percentage of Lake Nona residents because they cherish their ecosystem and community.

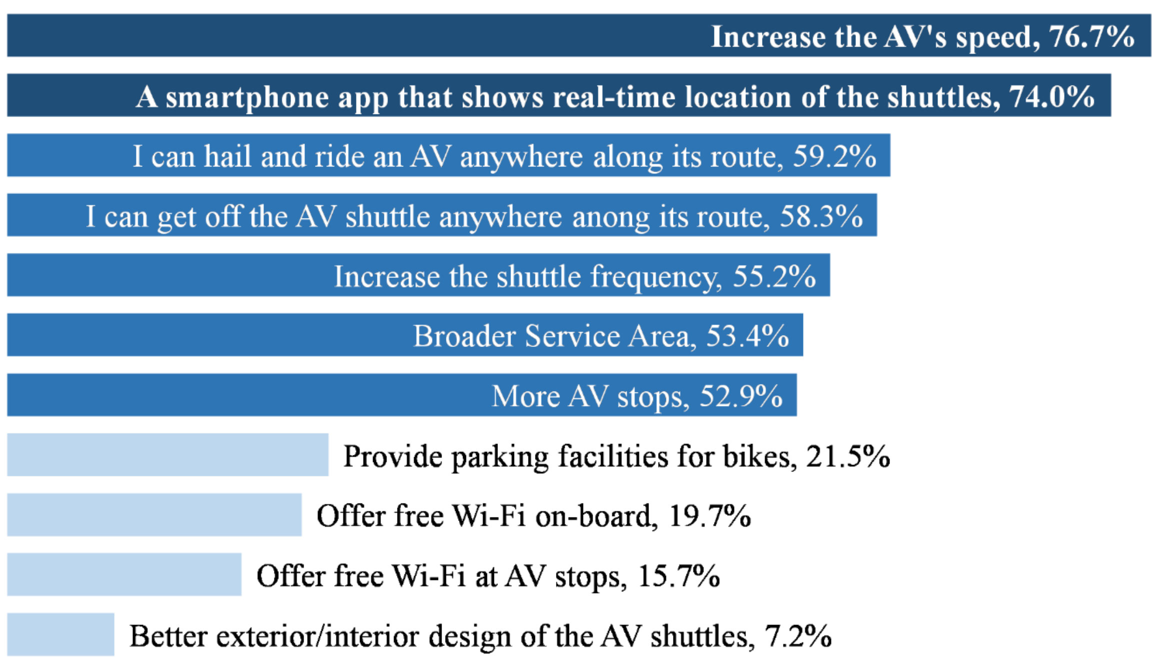
8. *Recommendations to Improve AV Shuttle Usage*

Although the Move Nona AV shuttle system is a leading AV-based microntransit program in the US, it is still in the early stages of becoming a mature, well-functioning public transit system that can attract substantial numbers of loyal users. Therefore, considering what new features and services might improve the current system is important to increasing ridership. Otherwise, after the initial curiosity dissipates, the service's AV shuttles will eventually remain an expensive investment rather than a feasible transportation method.

Figure 7-13 below lists facilities or features that, if added to the Move Nona system, may encourage ridership according to survey respondents. The survey question dedicated to soliciting these suggestions was 2.13. Based on the data analyses, subsections 7.8.1 to 7.8.4 offer four strategic recommendations.

Figure 7-13

Features/Services That Encourage AV Usage (n = 223)



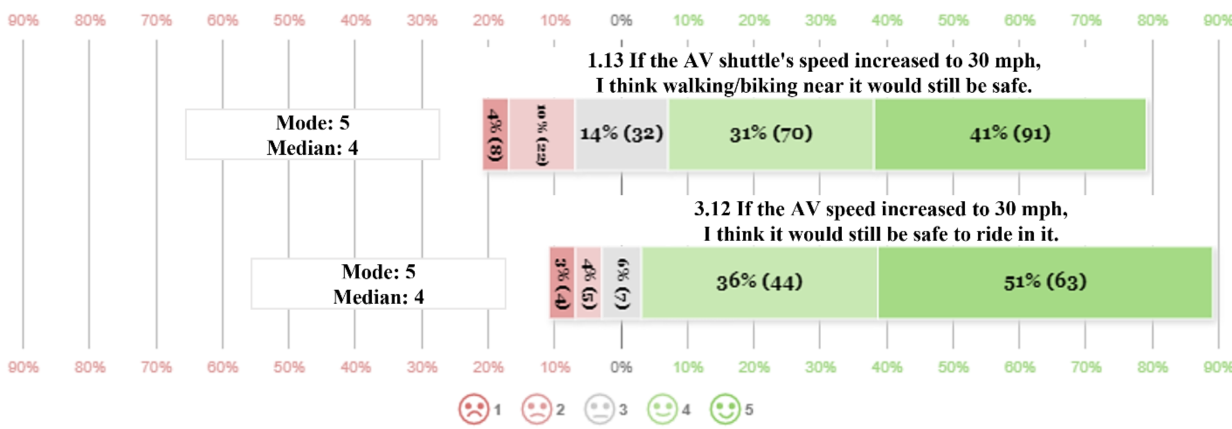
Note. Data from the Move Nona survey. The selections were proposed by subject-matter experts from the University of Florida research team, FDOT, and Beep. The research team used a multiple-answer question (2.13) to obtain the result. 128 respondents provided 1,101 answers. The percentage indicated how many respondents selected a particular choice.

1. Recommendation 1: Speed Increase

According to respondents, the service change that would most effectively attract new ridership would be to increase the AV shuttle operating speed; 76.7 percent of respondents advocated for a speed increase. From the comment section of the survey, some respondents complained that the low-speed AV shuttles had become an obstruction in traffic. The Move Nona AV shuttles' current operating speeds of 12.5 mph have made passengers anxious, and drivers agitated. The AV's low speed was also the top reason non-riders did not use the service (see subsection 7.6.2 and **Figure 7-11**). To explore what respondents might consider a more acceptable speed, questions 1.13 and 3.7 (discussed in section 7.7) inquired about an increase to 30 miles per hour (the speed limit of the neighborhood). **Figure 7-14** demonstrated that more than 80 percent of the respondents had no safety concerns about the speed increase and favored the new standard.

Figure 7-14

Respondents' Opinions about a Speed Increase to 30 mph



Note. Data is from questions 1.13 and 3.12 of the Move Nona survey.

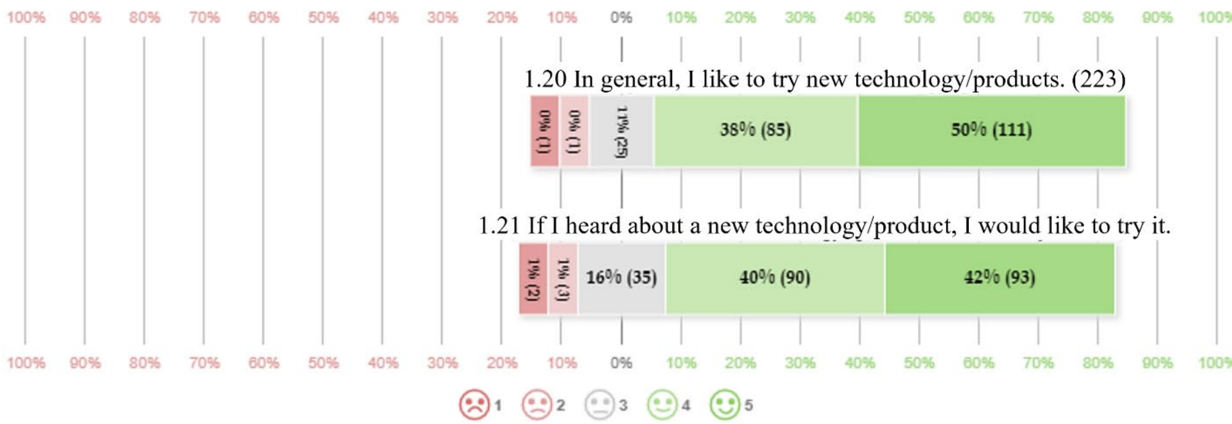
2. Recommendation 2: The Move Nona App

The second most appealing service addition, as suggested by 74 percent of the respondents, was a smartphone app that precisely showed the AV shuttles' real-time locations. Public transit users in the area are often upset about missing their bus or shuttle and find transit schedules unreliable. Many people must drive to avoid delays or waiting excessively long hours. For the Move Nona AV system, two respondents commented that the quality and reliability of the existing Move

Nona app were unpleasant, and that they were looking forward to having an updated one. At the same time, reflected by the findings from the "personal innovativeness" cluster of constructs (**Figure 7-15**), fewer than 2 percent of the respondents claimed that they disliked new technologies or products. Such a minor number implies that Lake Nona residents are passionate about novel technology. Considering their high education level, they could rapidly understand how to use the smartphone app to arrange their trips and schedule.

Figure 7-15

Questions about Respondents' Acceptance to New Technology



Note. Data is from questions 1.17 and 1.18 of the Move Nona survey.

3. Recommendation 3: On-Demand Service

According to Beep and Tavistock Development Company, the objectives of the Move Nona program, at least in the short term, are to serve the Lake Nona residents and demonstrate the new AV technology to attract potential property buyers or renters. Hence, three fixed-route lines were sufficient to fulfill their requirements. Only the Green Line (see **Figure 7-1**) had regular, long operation hours. In order to realize long-term investment plans that incorporate AV into the city's public transportation, the service will need to offer on-demand rides. Microtransit service with high flexibility—where people can hail and ride and then get off an AV anywhere along its route—will attract more users. As with other rideshare services, a flexible microtransit option could also reduce private vehicle trips.

However, technological barriers and funding obstacles stand in the way of a more reliable, flexible on-demand microtransit service. Not all companies, even with the support and endorsement of government agencies, could receive the continuous investment needed to afford a fleet of AV shuttles before becoming profitable. For instance, the price of a single Navya AV was $300,000 USD (Cheng, 2018). Sustaining an on-demand AV shuttle service would incur other inevitable expenses, such as marketing, staffing the management team, and hiring software engineers to create the smartphone app. Successfully launching on-demand AV service requires meticulous consideration, transportation simulation, and, likely, still-to-come technological improvements.

4. Recommendation 4: Serving Older Population

A safe and convenient public transportation system is an essential, practical approach to enhancing social equity and justice. For example, the elderly who were incapable of driving or unwilling to drive frequently could still easily travel around if there was a trustworthy AV shuttle system in the neighborhood. By making minimum design and quality improvements, an AV service like Move Nona can become friendlier to people over 65 while providing a broader service area and enhancing ride smoothness.

Regarding the Move Nona survey, about 3.59 percent of the respondents were older than 65, and 12.56 percent were older than 55. Given that the size of the former group was small (n = 8) and that everyone in the latter group would reach at least 60 years old within five years, it was more appropriate to analyze the latter's data. Around half of people older than 55 in Lake Nona are retired. 60.7 percent of this group are willing to walk less than one-quarter of a mile to get to the nearest AV stop from home, and 53.6 percent wanted a walking time of no more than 10 minutes. In other words, they demanded an AV stop within their block.

Chapter 8. Move Nona's Effectiveness Scores

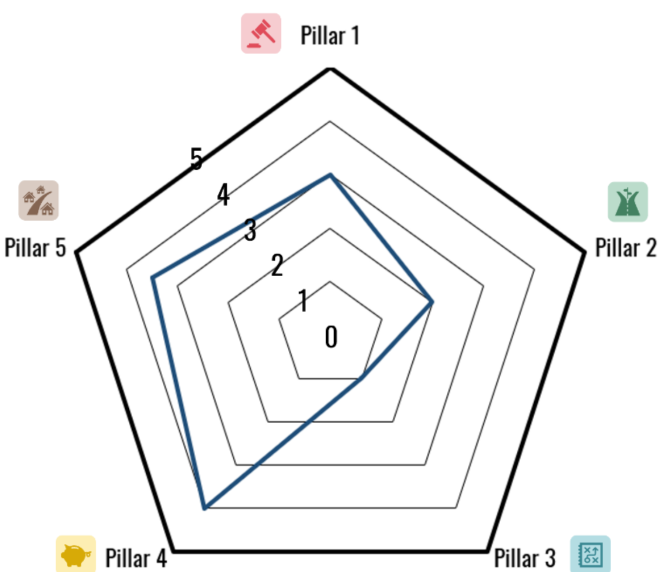
1. Overview

By applying the AVEE Framework to the Move Nona AV shuttle program as a case study, this chapter exemplifies how to quantify an AV system's effectiveness on a 0–5 scale. The measuring procedures are as follows:

1. Review all the elements (sub-criteria) and scoring metrics, listed in Chapter 4.
2. Display how to use the corresponding evidence and literature collected, providing data sources and reasoning along the way.
3. Calculate each element score and normalize it if necessary (symbol: $X_{\text{Element } n}$).
4. Aggregate and average the element scores to get criteria and pillar scores.
5. Present the result by a visualized diagram (see **Figure 8-1** as an example).

Figure 8-1

An Example of the Evaluation Outcome



Note. The outcome of evaluating the Move Nona system belongs to the authors and does not necessarily reflect the attitudes or beliefs of FDOT. The authors also recognize that the Move Nona AV program does not benefit from the same level of investment as the proposed BUILD Grant LAMN buildout; therefore, it would be appropriate to reassess AV operations in Lake Nona once those improvements are implemented.

2. *Score of Pillar 1 – Policy and Government Support*

Table 8-1 below presents the element contents, scoring metrics, and outcomes with reasons and sources used to arrive at Move Nona's final score for Pillar 1: Policy and Government Support. For a detailed explanation of Pillar 1, its criteria and elements, and methods to identify and gather essential data and literature, refer to section 4.3 in Chapter 4.

Table 8-1

Score of Pillar 1: Policy and Government Support

Criterion 1.1: **Legislative support of the AV-based microtransit system**	
Element 1.1.1	Does prohibitive or regulatory AV legislation exist at the **state** level? (E.g., transit, funding, operations, infrastructure design and maintenance, safety, etc.)
Explanation	This index captures whether the state government has already passed laws regulating the selection, funding, design, safety, operations, and maintenance of AV/AV-based microtransit systems. Having existing laws and regulations could reduce possible legal problems and ambiguities. Potential investors could also plan for their AV programs according to the laws and regulations.
Scoring metrics	1. Yes, with law enforcement – 5 2. Yes, but only guidance – 4 3. Yes, but only for a testing/pilot project – 3 4. Not specified, but AVs are not prohibited – 2 5. Under preparation or debating – 1 6. Prohibited – 0
Score	5
Reason	1. Florida legislators voted to approve House Bill 7027 in 2016 and House Bill 311 in 2019, becoming the first state in the United States to legalize fully autonomous vehicles on public roads. 2. The element received a 5 because the current law covered topics including AV operation, compliance with traffic and motor vehicle laws, and testing (Fla. Stat. § 316.85, 2022). 3. The state has edited and refined the laws and regulations multiple times in the past years to keep them up to date.
Element 1.1.2	Does the **county** government have AV-targeted ordinances?
Explanation	This index captures whether the county government has formulated ordinances guiding the design and implementation of AV or AV-based microtransit systems. The county government could adopt and enforce the state law.
Scoring metrics	1. Yes, with law enforcement – 5 2. Yes, but only guidance – 4 3. Yes, but only for a testing/pilot project – 3 4. Not specified, but AVs are not prohibited – 2 5. Under preparation or debating – 1 6. Prohibited – 0
Score	5
Reason	Orange County adopts and supports the state AV laws.

Element 1.1.3	Does the **local** government have AV-specific rules or regulations?
Explanation	This index determines if a local government has already adopted regulations that instruct the usage and operation of AV or AV transit systems
Scoring metrics	1. Yes, with law enforcement – 5 2. Yes, but only guidance – 4 3. Yes, but only for a testing/pilot project – 3 4. Not specified, but AVs are not prohibited – 2 5. Under preparation or debating – 1 6. Prohibited – 0
Score	5
Reason	1. The city of Orlando adopts and supports the state AV laws. 2. It has also adopted the National Association of City Transportation Officials' Autonomous Urbanism guidelines to improve AV readiness (City of Orlando, 2020).
Element 1.1.4	Do existing master/comprehensive transportation **plans** authored by city/state/county/transit/metropolitan planning organizations include AV or AV transit considerations?
Explanation	Most legislation regarding funding allocation require documented stakeholder support and, in some instances, financial partnering. This index captures, at the planning level, the funds and partnerships available for an AV system and if AV transit development is emphasized or prioritized.
Scoring metrics	1. Yes, there are specific AV/AV transit plans comprising critical elements like implementation goals, strategies, and timelines – 5 2. Yes, multiple comprehensive or transportation plans include or prioritize AV/AV transit development goals and strategies – 4 3. Yes, some plans have AV/AV transit considerations and implementation suggestions – 3 4. Yes, but only have general ideas of AV transit development – 2 5. AV considerations mentioned in government reports instead of plans – 1 6. No – 0
Score	5
Reason	1. The city of Orlando published a Future-Ready City master plan in 2020, which will contain objectives and strategies to implement AV systems. 2. The County's Sustainable Operations and Resilience Action Plan (SOARP) outlines goals for expanding AV/EV infrastructure in strategic areas of the County. 3. As mentioned in section 3.2, FDOT adopted a CAV business plan in 2019 and has since actively implemented the Florida's Connected and Automated Vehicle Initiative. 4. MetroPlan Orlando, the metropolitan planning organization for the Orlando region, has also completed a CAV readiness study, which identifies a coordinated set of actions across entral Florida jurisdictions.
Element 1.1.5	Can the AV transit system align with **current traffic laws** and regulations?
Explanation	This index captures whether an AV transit system conforms to the current transportation laws, which may include: 1. Speed limit 2. Vehicle dimension 3. Safety devices 4. Lighting and signaling 5. Software updating requirements

Scoring metrics	1. [0, 5] depends on how many of the abovementioned rules are met. If a particular rule was not met, a 0.5 will be deducted. 2. The element might not be applicable if there are no traffic laws in place.
Score	4.5
Reason	1. Fla. Stat. § 319.145 requires that AVs in Florida must be operated in compliance with the applicable traffic and motor vehicle laws of this state. 2. The Move Nona AV shuttle models (Navya) do not operate in defiance of any regulation. 3. The service suffers a 0.5-point deduction because the law does not require AV inspections to ensure the systems are kept up to date with the latest self-driving software (Langino et al., 2017).
Criterion 1.2: Government administrative support for the AV-based microtransit system	
Element 1.2.1	Does the local government entity or the designated department of transportation's district possess a dedicated AV or AV transit **department/office**?
Explanation	This index captures the level at which the government entity is equipped to manage and advance new AV or AV transit projects. Possessing a dedicated office reflects a higher determination in implementing AV services.
Scoring metrics	1. Yes – 5 2. Yes, but not dedicated – 4 3. Yes, but at an early stage of development – 3 4. Planned and ready to implement/establish – 2 5. Planned, but not yet implemented – 1 6. No office/department planned – 0
Score	4
Reason	1. FDOT's central and district offices, e.g., the Statewide Traffic Engineering and Operations Office, the Transportation Systems Management and Operations Program (TSM&O), FDOT District 5, Traffic Incident Management (TIM), and the Transportation Department of Orlando, are responsible for AV projects in central Florida. 2. The service suffers a 1-point deduction because these offices are not dedicated to AV transit affairs.
Element 1.2.2	Does the government entity possess AV **specialists** or **leads** responsible for the management and operations of an AV transit system?
Explanation	This index captures the level of expertise present within the government entity, important for its ability to operate and maintain an AV transit system. Having dedicated AV specialists or leads reflects a higher determination in implementing AV services.
Scoring metrics	1. Yes – 5 2. Yes, but has other secondary duties/titles – 4 3. Not primary dedication – 3 4. Under development, with a hiring plan in place – 2 5. No, but can find someone in charge when needed – 1 6. No – 0.
Score	5
Reason	FDOT departments, including TSM&O, the Central Florida AV Partnership (CFAVP), MetroPlan Orlando, Orange County, and the city of Orlando's transportation department have specialists or individuals in charge, overseeing different AV programs across the state.

Element 1.2.3	Does the government agency have history of funding/supporting new transportation **initiatives**?
Explanation	This index examines whether a government agency is prone to fund a new transportation initiative, and dictates the level of documentation, correspondence, stakeholder support, and measures of effectiveness required for deploying an AV transit service.
Scoring metrics	1. Yes, fully covered/dedicated – 5 2. Yes, partially/depends on the elected governor/officer in charge – [1, 4] 3. No – 0.
Note	Different parties and interest groups might hold distinctive opinions on AV technology.
Score	5
Reason	FDOT and its partners funded several CFAVP projects, such as the I-75 frame, PedSafe, SR 434 Pilot, and FUTURe CITy Initiative (FDOT, n.d.). They also funded other similar AV shuttle programs, like the one in Gainesville.
Element 1.2.4	Is it a **government-endorsed** program?
Explanation	This index captures the level at which the government entity has publicized its support for AV transit, e.g., leading/actively participating in the projects, formal declarations of support, dedicated AV funding programs, amendments to prohibitive legislation, etc.
Scoring metrics	1. Yes, led or actively engaged by the government – 5 2. Yes, government participates but does not lead – 4 3. Promoted or granted by the government – 3 4. Neither supported nor disallowed by the government – 2 5. No government involvement – 1 6. Against/criticized by the government – 0
Score	3
Reason	1. Move Nona AV shuttle program's investor was Tavistock Development Company, a private real estate development company without direct financial support from the government. 2. However, the city of Orlando, Orange County, and FDOT have helped to promote the service actively via policy support, media, press, and community events, preparing for the later BUILD Grant project expansion.
Element 1.2.5	Does the government have a **history** of successfully passing new (or changing existing) transportation laws and polices?
Explanation	This index indicates the effectiveness and efficiency of a government entity in passing new transportation laws and/or amending outdated policies, revealing the government entity's ability to take the necessary steps to transition to AV transit systems. Past successes/failures could be a reliable predictor of future results.
Scoring metrics	1. Yes – 5 2. Depends on the elected governor/officer in charge – [1, 4] 3. No – 0.
Score	5
Reason	1. Literature suggests that Florida played a leading role in exploring and implementing new AV technology and projects and was substantially supported by the legislative branch (Hayes, 2021; Langino et al., 2017). 2. Laws and regulations related to AVs, including Florida Statutes 316.003, 316.85, 319.145, 339.175, 339.64, 339.83, and 627.0653, have been updated and amended multiple times, suggesting strong legislative support.

Note that the University of Florida research team provided the scores and reasons, which may not represent the views of FDOT and might be subjective. Future users of the AVEE Framework could engage more stakeholders and experts through multiple workshops to rate and then calculate the average score to mitigate bias. This statement is applicable to all the following scoring results of the Move Nona assessment.

According to **Table 8-1**:

$X_{\text{Element 1.1.1}} = 5$, $X_{\text{Element 1.1.2}} = 5$, $X_{\text{Element 1.1.3}} = 5$, $X_{\text{Element 1.1.4}} = 5$, and $X_{\text{Element 1.1.5}} = 4.5$

$X_{\text{Element 1.2.1}} = 4$, $X_{\text{Element 1.2.2}} = 5$, $X_{\text{Element 1.2.3}} = 5$, $X_{\text{Element 1.2.4}} = 3$, and $X_{\text{Element 1.2.5}} = 5$

By aggregating and averaging the element scores:

Criterion 1.1 score = $\sum X_{\text{Element 1.1.1 to 1.1.5}} / 5 = 4.9$

Criterion 1.2 score = $\sum X_{\text{Element 1.2.1 to 1.2.5}} / 5 = 4.4$

The final score of Pillar 1 is (4.9 + 4.4) / 2 = **4.65**.

3. Score of Pillar 2 – Infrastructure and Technology

Table 8-2 below presents the element contents, scoring metrics, and outcomes with reasons and sources used to arrive at Move Nona's final score for Pillar 2: Infrastructure and Technology. For a detailed explanation of Pillar 2, its criteria and elements, and methods to identify and gather essential data and literature, refer to section 4.4 in Chapter 4.

Table 8-2

Score of Pillar 2: Infrastructure and Technology

Criterion 2.1: Infrastructure facilitating the AV-based microtransit system	
Element 2.1.1	What is the roadway's **Pavement Condition Index** (PCI) score?
Explanation	This performance measure adopts the ASTM's (2020) PCI to measure road quality. PCI is a numerical index used to indicate a pavement section's condition by assigning it one of seven classifications: Good (85-100), Satisfactory (70-85), Fair (55-70), Poor (40-55), Very Poor (25-40), Serious (10-25), and Failed (0-10).
Scoring metrics	PCI's calculation method is a visual survey of the amount and types of distress in a pavement. When applying the PCI score to the element: 1. For roadways within AV transit system operations with a PCI score of Good, Satisfactory, or Fair, the criterion score is calculated by converting the PCI score from a [0-100] scale to a [0-5] scale; divide PCI score by 20. 2. The criterion will receive a zero for roadways with a PCI score of Poor or below (a PCI score of 55 to 0).
Score	4.85
Reason	The research team assessed the pavement condition of Move Nona's Green Line via a visual survey in July 2022. Based on PCI, the pavement (Tavistock Lakes Blvd.) was in excellent condition, without any distress, such as alligator cracking, bleeding, block cracking, and depressions (**Figure 8-2**). Two minor issues were that two intersections had pavement material shift from asphalt to bricks, and there were about three shallow holes. The PCI score assigned was 97/100, or 4.85/5. **Figure 8.2** A Section of Move Nona Route 1  Note: Photo courtesy of Yanghe Liu (2022).

Note	Like traditional vehicles and buses, AV shuttles can operate on regular roads, but their advanced radar/lidar systems are sometimes more sensitive to obstacles and pavement distress. A good PCI score can offer a minimum road quality guarantee for implementing an AV service.
Element 2.1.2	Does the **roadway design** impede AV operations?
Explanation	This element focuses on roadway design that accommodates AVs and identifies atypical roadway design features that may hinder AV operations, which may include: 1. Vertical horizontal variations that are present in roundabouts and intersection, e.g., speed bumps, truck aprons, raised crossings, speed tables 2. The presence of traffic/bicycle separation methods, e.g., flexible delineators and raised curbs 3. The presence of landscaping/trees adjacent to AV lanes with the potential to obstruct sensors
Scoring metrics	A visual survey of the routes to identify the abovementioned obstacles is needed. 1. Roadways without street design features that block the AV operation – 5 2. Roadways with minor issues (e.g., trees distract the sensors) – 4 3. Roadway design issues that need moderate/major/full fixing or upgrading, depending on time cost and budget – 1/2/3 4. Roadways unfit for AV operation or too expensive to upgrade – 0
Score	4
Reason	The research team conducted two virtual surveys and only identified the issue of fast-growing vegetation, which causes the AV shuttles to interpret new growth as being an unmapped obstruction in its route. Such changes in vegetation can cause the AV shuttle to brake suddenly.
Element 2.1.3	Do **street signs** impede AV operations?
Explanation	This element captures the extent to which street signs (e.g., parking, speed, wayfinding, traffic guidance signs) are clear, visible, and consistent for autonomous detection and decision-making. Examples of related issues may include: 1. Signs lack contrast, use of stylized lettering, highly reflective signage, inconsistent wayfinding signage (e.g., variable use of state/city/county naming conventions and different fonts and styles). 2. Roadway marking have visible wear, or markings are adjacent or perpendicular to travel lanes with the potential to interrupt proper sensor readings (e.g., stop bars, bicycle lane buffers, and crosswalks). 3. Crosswalk markings have high levels of wear or above-average reflective properties.
Scoring Metrics	A visual survey of the routes to identify the abovementioned obstacles is needed. 1. Street signs without abovementioned issues blocking AV operation – 5 2. Street signs with minor issues – 4 3. Street sign issues that need moderate/major/full fixing or upgrading, depending on time cost and budget – 1/2/3 4. Street signs unfit for AV operation or too expensive to upgrade – 0
Score	5
Reason	1. Move Nona Route 1 is almost a fixed, straight lane inside a residential area, which does not have the issue of a complicated street sign, i.e., all street and pavement signs are uniform and clear. 2. The AV shuttle also did not share the lane with bikes and pedestrians because there were designated bike lanes and sidewalks.

Element 2.1.4	Is the supporting **infrastructure** ready to accommodate AV transit?
Explanation	This index captures the extent to which there is a network of supporting infrastructure to accommodate AV transit operations and encourage AV usage. Some key features are: 1. Bus bays/pull-outs 2. New, dedicated AV transit lanes 3. Original street with more multiple lanes 4. Original streets have dedicated bike/pedestrian lanes 5. Posted speeds higher than AV transit travel speeds 6. Parking spaces for cars and bikes (to assist trip connection)
Scoring metrics	1. Infrastructures with major/moderate/minor/no challenges or upgrade needs will receive, depending on time, cost, and budget, a score of 1 to 5. 2. Identified infrastructure challenges that require costlier solutions, such as two-lane roadways without (or impossible to add) bus bays/pullouts and posted speeds above AV travel speeds, or an infrastructure challenge that otherwise requires construction or widening of lanes, should receive a score of 0. 3. The absence of dedicated transit lanes and/or separated bicycle/pedestrian lanes does not guarantee a 0. 4. If the road network of neighborhood does not meet the minimum requirement for operating a bus, it would receive a score of 0. Please refer to roadway owner agency guidance for traveling public acceptable levels of service. For example, FDOT's level of service targets for the state highway system are "D" in urbanized areas and "C" outside urbanized areas (Office of Systems Planning, FDOT, 2019).
Note	Low AV transit travel speeds and delayed stopping/turning movements present challenges on two-lane roadways without bus bays. Therefore, having the above-listed features are critical to infilling a new AV system and attracting users.
Score	3.5
Reason	Over 90% of Move Nona Route 1 were two-lane roadways (see **Figure 8-3**) without bus bays/pullouts. As a result, AV shuttles would often delay general traffic behind them due to its speed of 12.5 mph (50% lower than the speed limit), causing driver frustration. Nevertheless, developers could utilize street parking spaces all along the route and convert them into pullouts rather than expanding the existing streets. The score would thus be 3.5 (minor to moderate upgrade needed). **Figure 8-3** A Bird View of Route 1's Segment  Note. Courtesy of Google Maps.

Element 2.1.5	Can AV users get high-speed, reliable broadband **internet** coverage?
Explanation	The success of AV operations is closely associated with the resilience, redundancy, and speed of internet. AV transit users often demand an app showing real-time locations of the vehicles and schedules. Determining the “success” relies on identifying existing 4G/5G or wifi technologies with faster speed available within the AV transit systems, particularly at the AV stops or even along the routes.
Scoring metrics	1. High-speed free wifi coverage at AV stops (paid by the operating company or the community) – 5 2. No free wifi but with good 4G/5G coverage in the service area – 4 3. Internet speed meets 3G standard – 3 4. Internet speed meets the basic requirement (see note below) to run the AV service’s app and interactive maps – 2 5. Partial/unstable internet coverage in the area – 1 6. No coverage, or coverage too slow – 0.
Note	The minimum internet speed requirement here is the speed of 3G networks, which is about 3.1 megabits per second, allowing internet surfing and app usage. If the AV transit system is a fixed-route shuttle service with schedule provided, this criterion could be omitted.
Score	3
Reason	1. No free wifi coverage. 2. 4G/5G coverage was good except near the Boxi Park, which was a major AV stop, so the score was 3.
Criterion 2.2: Quality of the autonomous vehicle	
Element 2.2.1	Do AVs have advanced vehicular **devices** supporting driving automation?
Explanation	This index measures whether an AV has a complete set of advanced devices supporting SAE’s level 4 of driving automation, enabling 3D vision, environment recognition, and real-time obstacle detection and prioritization. Critical features may include: 1. driveline/power system performance 2. high-voltage battery 3. steering, braking, charging systems. 4. Lidar sensors 5. Detection lasers 6. Odometry 7. GNSS antenna 8. Stereovision cameras
Scoring metrics	1. AV programs use models that have passed all tests or been successfully implemented elsewhere, including Navya’s Arma, EasyMile’s EZ10, Local Motor’s Olli, and Baidu’s Apolong – 5 2. AV programs use new models matching the abovementioned successful AV shuttle models but require additional testing – 4 3. AV programs use new models that meet the ISO 22737:2021 minimum requirements – 3 4. AV models have failed to meet the SAE level four requirements – 0
Note	Experts and testing runs are needed when making decisions and evaluations.
Score	5
Reason	Move Nona had a good operation record, and it used the Navya’s Arma shuttle, a popular model tested and implemented worldwide.

Element 2.2.2	Have the AVs passed road and performance **tests**?
Explanation	This index examines whether an AV can pass road and performance tests and is ready to set out. Models successfully implemented elsewhere include Navya's Arma, EasyMile's EZ10, Local Motor's Olli, and Baidu's Apolong.
Scoring metrics	1. Models have passed local road and performance test – 5 2. Models have been successfully implemented in other places with similar road conditions/environment – 4 3. Models have succeeded elsewhere but need minor modification and localization – 3 4. Moderate modification needed – 2 5. Major modification or improvement needed – 1 6. Otherwise – 0
Score	5
Reason	Same as 2.2.1.

According to **Table 8-2**:

$X_{\text{Element 2.1.1}} = 4.85$, $X_{\text{Element 2.1.2}} = 4$, $X_{\text{Element 2.1.3}} = 5$, $X_{\text{Element 2.1.4}} = 3.5$, and $X_{\text{Element 2.1.5}} = 3$

$X_{\text{Element 2.2.1}} = 5$, $X_{\text{Element 2.2.2}} = 5$

By aggregating and averaging the element scores:

Criterion 2.1 score = $\sum X_{\text{Element 2.1.1 to 2.1.5}} / 5 = 4.07$

Criterion 2.2 score = $\sum X_{\text{Element 2.2.1 to 2.2.2}} / 2 = 5$

The final score of Pillar 2 is (4.025 + 5) / 2 = **4. 535**.

4. Score of Pillar 3 – Service and Management

Table 8-3 below presented the element contents, scoring metrics, and outcomes with reasons and sources used to arrive at Move Nona's final score for Pillar 3: Service and Management. For a detailed explanation of Pillar 3, its criteria and elements, and methods to identify and gather essential data and literature, refer to section 4.5 in Chapter 4.

Table 8-3

Score of Pillar 3: Service and Management

Criterion 3.1: Service quality of the AV-based microtransit system	
Element 3.1.1	Is the AV-based microtransit service **proximate** to the community?
Explanation	This index reflects the relative convenience of accessing the AV shuttle as a transit mode choice, measuring how many households/residents live within walking distance (½ mile radius area or a 10-minute walk) of an AV service stop, in the case of hail-and-ride services, its route.
Scoring metrics	1. If the AV-based microtransit service offers a door-to-door pick-up and drop-off (no need to walk), the element receives a score of 5. 2. If the AV-based microtransit service is fixed-route with stops, then convert the percentage of households within walking distance of the AV stops over the total household number to a scale of zero to five. 3. One alternative is to conduct a community survey and estimate the percentage of respondents who live within walking distance of getting the AV service, and then convert the result to a scale of zero to five. $\frac{\text{Households or Respondents living in the service area}}{\text{Total Households or Respondents}} \times 5$
Score	2.62
Reason	1. Based on the Move Nona survey, among 219 respondents, 115 lived with walking distance from a nearest AV stop. Score = (115 ÷ 219) × 5 = 2.62 2. Since Move Nona is a demonstration program not primarily serving the residents (it also serves visitors and potential property buyers), people living near the AV stops might not use the shuttle. Thus, calculating the outcome directly from the AV riders who took the community survey and living within walking distance of an AV stop would be more accurate.
Element 3.1.2	Can the AV-based microtransit service let users travel **faster**?
Explanation	Travel time is a principal measure of public transportation service. People who used the framework could estimate the travel time difference based on the AV speed and distance or take AV rides in person.
Scoring metrics	1. 25%+ faster than the current travel time – 5 2. 5-25% faster than the current travel time – 4 3. 0-5% faster than the current travel time – 3 4. Same as current – 2.5 5. 0-5% slower than the current travel time – 2 6. 5-25% slower than the current travel time – 1 7. 25%+ slower than the current travel time – 0

Score	1
	The distance between Laurate Park and Boxi Park is 1.1 miles. Using an AV shuttle with a speed of 12.5 mph would take around 5 to 6 minutes. Comparing to driving or cycling, it would take at least 1 minute longer.
Element 3.1.3	Is riding the AV-based microtransit service **comfortable**?
Explanation	This index measures the experience of riding in an AV shuttle. The measurements are similar to conventional cars, including: 1. The convenience of door access 2. Interior space (head and legroom) 3. Smoothness of the ride 4. Seat size and quality 5. Noise level when riding
Scoring metrics	1. Prepare a community survey targeting AV riders/passengers. 2. Use one or more attitude statement questions to ask the respondents about the five abovementioned aspects of comfort levels, using 1-5 Likert scale (from "Strongly Disagree" to "Strongly Agree") for answer options. 3. Sample questions could include: "I think the cabin size is spacious"; "I think the seats are comfortable"; "I think the noise is finely controlled when riding." 4. Assign values 1-5 to match those results (converting ordinal data to numerical data) and obtain mean and mode outcomes. 5. Find the average of the outcomes to be the element score.
Note	1. For assisting vendor selection: users could refer to the standards of bus entrance in the research area and seat pitch/width of bus (typically 39 inches wide) or major airlines. 2. An AV without ADA accommodation features (a lift ramp or a wheelchair space) can only get a maximum score 2.5.
Score	3.9
Reason	See community survey results from subsection 7.5.4.
Element 3.1.4	Does the AV service have a high-quality **smartphone app**?
Explanation	This index captures whether an AV-based microtransit system has a smartphone app/platform to help trip planning more efficient and precise. Two minimum functions are: 1. A real-time map showing the locations of all the stops and vehicles 2. Schedules of all vehicles and each stop Two recommended functions are: 1. A straightforward user interface 2. Multiple languages (at least English and Spanish in the United States)
Scoring metrics	1. An app with a complete set of functions, including on-demand ride requests – 5 2. An app with at least the two minimum functions and one of the recommended functions – 4 3. An app with the two minimum functions only – 3 4. An app with problems impairing one of the minimum functions – 2 5. An app with problems impairing both minimum functions – 1 6. No smartphone app or the app is not working – 0
Note	The AV shuttle service provider should also print and place service maps and schedules at all AV stops, helping people with no smartphones.
Scoring	4

Reason	The app's user interface is easy to understand and use. The two main functions, a real-time map and schedule, are straightforward and clear (see **Figure 8-5**). **Figure 8-4** User Interface of the Ride Beep App  Note. The Ride Beep app included a real-time map and the shuttle schedule. However, the element got 1-point deduction because the smartphone app was in English only, whereas Lake Nona has a large Spanish-speaking population.
Criterion 3.2: **Management quality of the AV-based microtransit system**	
Element 3.2.1	Is there a professional **management** team operating the system?
Explanation	This index captures whether the AV system is professionally operated with good quality and high standards, with duties such as cleaning the cabin, keeping the data, marketing, networking, and problem-solving.
Scoring metrics	1. Yes – [3, 5] 2. Under development – [1, 3) 3. No – 0
Score	5
Reason	Beep has a professional management team, with specific members responsible for operating and monitoring the Move Nona platform, collecting and analyzing data, and providing solutions.
Element 3.2.2	Is there a routine **training** program for managers, operators, and engineers?
Explanation	This index captures the AV vendor's focus on education and preparedness. A training program ensures that managers, operators, and engineers are knowledgeable about AV system operations and understand how to respond to unexpected disruptions accurately and rapidly.
Scoring metrics	1. Yes – 5 2. Yes, but with high employee turnover rate – 4 3. Yes, but has no routine – 3 4. Occasionally – 2 5. Rarely – 1 6. No – 0
Score	4

Reason	According to Beep, all employees are highly trained, especially the Beep attendants, who would always be aboard the shuttle and ready to control it manually when incidents happened. However, since there was a shortage of labor in the market and a high turn-over rate, there was a 1-point deduction.
Element 3.2.3	Does the AVs receive sufficient and professional **maintenances**?
Explanation	This index captures the AV vendor's regular maintenance adherence. Users need to ask the operating company for data.
Scoring metrics	1. AVs receive required inspections and maintenances recommended by the manufacturer on a regular basis – 5 2. AVs receive required inspections and maintenance, but the latter was not from the manufacturer – 4 3. AVs receive inspections and maintenance occasionally – 3 4. AVs receive inspections and maintenance rarely – 2 5. AVs only receive maintenance when problems occurred – 1 6. No maintenance – 0
Score	5
Reason	From a visual survey, all AV shuttles are in good condition. Beep also confirmed that the AVs were receiving regular maintenance provided by Navya, the shuttle manufacturer.
Element 3.2.4	Availability of ridership **data** and operation log/records?
Explanation	This index captures the availability of AV ridership and operations data provided by the AV vendor to the public. Besides test/pilot programs, government funding will require ridership and incident data reports. Furthermore, an AV vendor looking to market the acceptance and utility of their system needs to demonstrate this success by transparently sharing this information.
Scoring metrics	1. The AV vendor keeps complete ridership and operations data, which are open to the public – 5 2. Data are not published but available by request – 4 3. Data is only available to designated groups – 3 4. Part of the data is available to designated groups – 2 5. Withholding data – 1 6. Absence of data – 0
Score	2.
Reason	Data (for example, daily ridership numbers) were available by request, but revenue and cost data were not available.
Element 3.2.5	Can the operator monitor and provide timely **responses** when incidents happen?
Explanation	This index captures the capability of the offering timely solutions or technical support (at least car towing service) by the vendor and operation team when facing accidents or incidences.
Scoring metrics	1. Immediate remote technical support and adequate number of prepared field service technicians – 5 2. Timely remote and field technical support available but contracted out – 4 3. Remote and field technical support available but experiencing service delay – [2, 3] 4. Either remote technical support or field service is not available – 1 5. Incidents causing service cancellation – 0
Score	5
Reason	Move Nona is a small-scale program. Thus, the incident response was fast. Also, Beep's remote command center had an excellent operation record in the TEDDY demonstration trial in Yellowstone Nation Park.

According to **Table 8-3**:

$X_{\text{Element 3.1.1}} = 2.62$, $X_{\text{Element 3.1.2}} = 1$, $X_{\text{Element 3.1.3}} = 3.9$, and $X_{\text{Element 3.1.4}} = 4$

$X_{\text{Element 3.2.1}} = 5$, $X_{\text{Element 3.2.2}} = 4$, $X_{\text{Element 3.2.3}} = 5$, $X_{\text{Element 3.2.4}} = 2$, $X_{\text{Element 3.2.5}} = 5$

By aggregating and averaging the element scores:

Criterion 3.1 score = $\sum X_{\text{Element 3.1.1 to 3.1.4}} / 4 = 2.88$

Criterion 3.2 score = $\sum X_{\text{Element 3.2.1 to 3.2.5}} / 5 = 4.2$

The final score of Pillar 3 is (2.358 + 4.3) / 2 = **3.54**.

5. Score of Pillar 4 – Financial Sustainability

Table 8-4 below presented the element contents, scoring metrics, and outcomes with reasons and sources used to arrive at Move Nona's final score for Pillar 4: Financial Sustainability. For a detailed explanation of Pillar 4, its criteria and elements, and methods to identify and gather essential data and literature, refer to section 4.6 in Chapter 4.

Table 8-4

Score of Pillar 4: Financial Sustainability

Criterion 4.1: Funding security and stability of the AV-based microtransit system	
Element 4.4.1	How **sufficient** is the proposed budget of the AV project?
Explanation	This criterion measures whether an AV-based microtransit project's budget is sufficient (covering all the costs) for its designated testing/demonstration period, or potentially in the long run. Literature suggests that almost all AV-based microtransit projects worldwide were testing/pilot programs, and many were free, implying that the success of such projects relied entirely (or at least extensively) upon stable funding sources, including the government, private investors, or public-private partnerships.
Scoring Metrics	1. A self-sufficient AV program (e.g., operating revenue, and advertising income) – 5 2. A partially self-funded AV program (has some operating revenue but still relies on venture capital investments or business loans) – 4 3. An AV program that primarily relies on venture capital investments and business loans – 3 4. Otherwise – 0 For a pilot/testing/demonstration AV project: 1. With promised/received funding covering the entire estimated cost – 2.5 2. With cost over funding – 0
Note	Users need to contact the operation company if the data (funding amount and operational cost) is not open to the public.
Score	2.5
Reason	As a demonstration program, Move Nona's sole funding source is Tavistock Development Company. Beep informed the research team that the project funding was sufficient; however, the exact revenue and cost data were not available.
Criterion 4.2: Possibility of becoming a long-term transit option	
Element 4.2.1	From the **financial sustainability** perspective, what is the AV-based microtransit system's potential of becoming a long-term public transportation option?
Explanation	Since the purpose of implementing an AV-based microtransit system is to provide a new public transit option for residents, it is essential to assess its effectiveness and whether it can play the same role as a bus system. If it can, the AV system is worth turning into a long-term transit method capable of receiving financial support from transit providers or the government.

	The suggested method is to compare the expenses of operating an AV shuttle and a public bus deployed in the city/region over their vehicle-mile (vehicle miles traveled, or VMT), and the steps are as follows: 1. Identify the annual cost of an AV shuttle (the initial capital cost of purchasing the vehicle itself should be annualized over its lifecycle), and then divide it by its annual VMT. 2. Estimate the average annual cost of a city bus, including the capital cost (should be annualized over its lifecycle) and operating costs (fuel and employee wages and benefits), and then divide it by its annual VMT.
Note	1. Users of the framework may adjust the range/interval of the cost gaps based on actual condition/needs. 2. The suggested life cycle of an AV shuttle, e.g., Navya Arma is 5 years. 3. The suggested life cycle of a city bus is around 10 to 12 years. 4. The city bus can be gasoline/diesel, hybrid, or electric buses depend on the actual condition, resulting in different costs. 5. The framework users can use the data of all city buses or buses in adjacent regions of the study area depending on availability.
Scoring Metrics	If the estimated annual cost of an AV shuttle per VMT is: 1. Less than average annual cost per VMT of a city bus – 5 2. Equal to the average annual cost per VMT of a city bus – 4 3. 0 – 5% more than the average cost per VMT of a city bus – 3 4. 5 – 10% more than the average cost per VMT of a city bus – 2 5. 10 – 25% more than the average cost per VMT of a city bus – 1 6. 25%+ more than the average cost per VMT of a city bus – 0
Score	0
Reason	The regional public transit system, LYNX, does not directly serve the Lake Nona neighborhood with the exception of one regional service route to VA Medical Center in the periphery of the neighborhood. Also, the Move Nona system was not designed or developed as an alternative or an enhancement to the public transit system. Given the minimal ridership and purpose of the Move Nona system, evaluating the feasibility of the service as a long-term transit option was determined to be not useful. However, we still calculated the result to illustrate how to use the tool. 1. According to LAMN (2019), the annual cost per AV shuttle in Lake Nona was $144,000, including purchasing the vehicle per se, annualized over the five-year lifecycle. 2. As LYNX is promoting electric-powered buses, Aber (2016) estimated the lifetime (12 years) cost of such a bus was around $1,180,000 ($98,333 per year), including purchasing, electricity, and maintenance costs. Also, the median salary of a bus driver is around $56,851 (Glassdoor, 2022). The estimated total cost of an electric bus would be around $155,000. 3. However, as a demonstration project with a route length of 1.7 miles, Move Nona AV shuttles would still have a low annual VMT. For example, if a shuttle ran the full route 4 times per hour, 8 hours per day for an entire year, its VMT would still be less than 20,000. In contrast, a public bus's VMT is at least 40,000 per year (Federal Highway Administration, 2018). 4. The results of 144,000/20,000 and 155,000/40,000 are 7.2 and 3.9. We found that operating an AV shuttle would be much more expensive than having an electric bus.

Element 4.2.2	From the **transit system efficiency** perspective, what is the AV-based microtransit system's potential of becoming a long-term public transportation option?
	Since a city bus and an AV shuttle have different loading capacity and route length, it is also reasonable to compare their efficiency. Thus, the framework adopts the classic transit system efficiency indicator: transit passengers per VMT.
Scoring Metrics	If the transit passengers of an AV shuttle per VMT is: 1. More than the average passengers/VMT of a city bus – 5 2. Equal to the average passengers/VMT of a city bus – 4 3. 0 – 5% less than the average passengers/VMT of a city bus – 3 4. 5 – 10% less than the average passengers/VMT of a city bus – 2 5. 10 – 25% less than the average passengers/VMT of a city bus – 1 6. 25%+ less of the average passengers/VMT of a city bus – 0
Note	1. Users of the framework may adjust the range/interval of the cost gaps based on actual condition/needs. 2. The framework users can use the data of all city buses or buses in adjacent regions of the study area depending on availability.
Score	N/A
Reason	BEEP's exact ridership and VMT data are not available.

Note. The University of Florida research team provided the scores and reasons, which do not represent the views of FDOT.

According to **Table 8-4**:

$X_{\text{Element 4.1.1}} = 2.5$

$X_{\text{Element 4.2.1}} = 0$, $X_{\text{Element 4.2.2}} = \text{N/A}$

By aggregating and averaging the element scores:

Criterion 4.1 score = $X_{\text{Element 4.1.1}} = 2.5$

Criterion 4.2 score = $\sum X_{\text{Element 3.2.1 to 3.2.2}} / 2 = 0$

The final score of Pillar 4 is (2.5 + 0) / 2 = **1.25**.

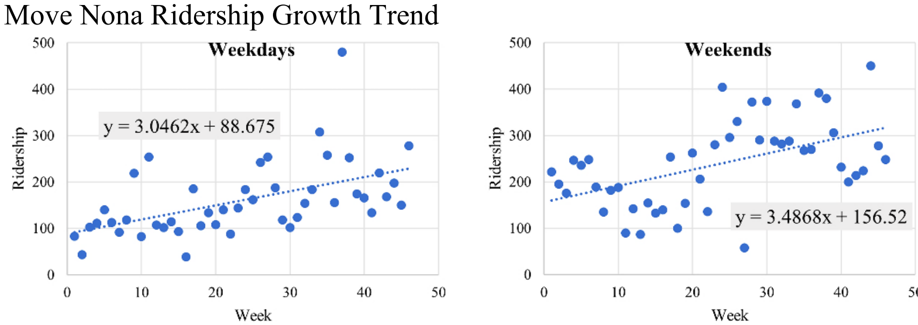
The final score of Pillar 4 is **1.25**. However, applying lessons learned from measuring a testing or demonstration AV shuttle service like Move Nona without exact revenue, expense, and VMT data to a more comprehensive AV program might cause bias and inaccuracies.

6. *Score of Pillar 5 – Ridership and Community Impact*

Table 8-5 below presents the element contents, scoring metrics, and outcomes with reasons and sources used to arrive at Move Nona's final score for Pillar 5: Ridership and Community Impact. For a detailed explanation of Pillar 5, its criteria and elements, and methods to identify and gather essential data and literature, refer to section 4.7 in Chapter 4.

Table 8-5

Score of Pillar 5: Ridership and Community Impact

Criterion 5.1: Ridership impact of the AV-based microtransit system	
Element 5.1.1	What is the AV **ridership** trend?
Explanation	This index captures the variations in recorded ridership experienced by the AV-based microtransit system throughout the implementation lifecycle and whether the ridership of the existing transit system increases or decreases.
Scoring metrics	Make a best-fit line of the ridership data and calculate the slope. 1. If the slope result is positive, then add it to 2.5 (maximum is 5). For example, a slope of 0.5 leads to an element score of 3. 2. Otherwise, deduct the slope value from 2.5 (minimum is 0). For example, a slop of -0.5 leads to an element score of 2. $\text{Slope} = \frac{\sum\left((x-\bar{x})\times(y-\bar{y})\right)}{\sum(x-\bar{x})^2}$ x is the operation day number, and the ridership of a day.
Score	N/A
Reason	1. The research team gathered daily ridership numbers between 4/19/2021 and 3/6/2022 from Beep. However, given the short duration of ridership data and other factors like the Covid-19 pandemic, the pattern of the data could not represent the actual impact in a normal setting unless having a more extended testing period. Thus, we caveat the element score. 2. Nevertheless, we draw the best-fit lines of weekday and weekend ridership data to demonstrate how to apply the abovementioned method. The slopes were 3.046 and 3.487, respectively (see **Figure 8-6**). **Figure 8.5** Move Nona Ridership Growth Trend  Note. Ridership data is from Beep.

Element 5.1.2	Can the AV-based microtransit system attract **repeat** passengers?
Explanation	This index captures an AV-based microtransit program's ability to retain users. It checks whether riders are willing to use the AV again.
Scoring metrics	1. Prepare a community survey targeting AV riders/users. 2. Use attitude statement questions to ask the respondents if they want to use the AV service again. 3. A sample question can be, "I plan to use the AV service again." 4. The answer choices can either be a 1-5 Likert scale, or "Agree/Disagree." 5. Find the percentage of the respondents with positive responses and multiply by 5 to arrive at the element score.
Score	3.81
Reason	1. The ratios of positive answers ("Agree" and "Strongly Agree") to the Move Nona survey questions 1.7 and 1.8 were 77.8% (99/128) and 75% (96/128). 2. The average of these numbers was converted to a scale of 5.
Element 5.1.3	Does the AV service **reduce** private car usage?
Explanation	This index captures how the AV-based microtransit system affects private car usage, signifying the importance of promoting an AV transit service.
Scoring metrics	1. Conduct a community survey to find the percentage of respondents (x) who have changed their travel method from driving to taking the AVs. Users can set a desired objective of car usage decreasing rate (y). 2. Divide x by y and multiply the product by 5.
Score	0.2
Reason	1. Move Nona is a small-scale demonstration AV program within a limited area of the neighborhood, and thus has insignificant impact on most residents' travel mode change. 2. Based on Question 2.8 and Question 3.3 of the survey, only 9 people who used to drive (n = 221) started to use the Move Nona AV shuttle with a fixed travel routine. 3. The element score = $(9 \div 221) \times 5 = 0.2$

Criterion 5.2:
Community acceptance of the AV-based microtransit system

Element 5.2.1	Does the community think the AV-based microtransit system is **useful**?
Explanation	This index measures community residents' perceptions of an AV program to understand whether they believe it is a useful and convenient public transit option.
Scoring metrics	1. Prepare a community survey targeting all residents. 2. Use one or more attitude statement questions and a 1-5 Likert scale (from "Strongly Disagree" to "Strongly Agree"). 3. A sample question might be: "I think the AV service is useful," or "I think the AV service can let me travel more conveniently." 4. Assign values 1 to 5 to match those results (converting ordinal data to numerical data) and obtain mean and mode outcomes. 5. Find the average of the outcomes to be the element score.
Score	3
Reason	Referring to the Move Nona survey results: Question 1.4: 2 (median) and 1 (mode) Question 1.5: 3 and 4 Question 1.6: 4 and 4 After assigning values and calculating the average, the element score is 3.

Element 5.2.2	Are the riders/users **satisfied** with the AV-based microtransit service?
Explanation	This index measures the AV-based microtransit service riders/passengers' perceptions to understand whether they are satisfied.
Scoring metrics	1. Prepare a community survey targeting all residents. 2. Use one or more attitude statement questions and a 1-5 Likert scale (from "Strongly Disagree" to "Strongly Agree"). 3. Sample questions might be: "I am satisfied with the AV service," or "I think most of my expectations towards AVs have been confirmed." 4. Assign values 1 to 5 to match those results (converting ordinal data to numerical data) and obtain mean and mode outcomes. 5. Find the average of the outcomes to be the element score.
Score	3.875
Reason	Referring to the Move Nona survey results (rider version): Question 3.13: 4 (median) and 4 (mode) Question 3.14: 4 and 3 Question 3.15: 4 and 4 Question 3.16: 4 and 4 After assigning values and calculating the average, the element score is 3.875.
Element 5.2.3	Is an AV-based microtransit system a valuable neighborhood **asset**?
Explanation	This index measures whether an AV shuttle is a critical asset to the neighborhood and is a factor in attracting current and new residents.
Scoring metrics	1. Prepare a community survey targeting all residents. 2. Use one or more attitude statement questions and a 1-5 Likert scale (from "Strongly Disagree" to "Strongly Agree"). 3. Sample questions might be: "I think having an AV shuttle service can make a neighborhood more attractive or positively influence moving decisions." 4. Assign values 1 to 5 to match those results (converting ordinal data to numerical data) and obtain mean and mode outcomes. 5. Find the average of the outcomes to be the element score.
Score	3
Reason	Referring to the Move Nona survey results (rider version): Question 3.13: 4 (median) and 4 (mode) Question 3.14: 3 and 4 Question 3.15: 2 and 1 After assigning values and calculating the average, the element score is 3.

According to **Table 8-5**:

$X_{\text{Element 5.1.1}}$ = N/A, $X_{\text{Element 5.1.2}} = 3.81$, $X_{\text{Element 5.1.3}} = 0.2$

$X_{\text{Element 5.2.1}} = 3$, $X_{\text{Element 5.2.2}} = 3.875$, $X_{\text{Element 5.2.3}} = 3$

By aggregating and averaging the element scores:

Criterion 5.1 score = $\sum X_{\text{Element 5.1.1 to 5.1.3}} / 2 = 2.01$

Criterion 5.3 score = $\sum X_{\text{Element 3.2.1 to 3.2.5}} / 5 = 3.29$

The final score of Pillar 5 is (2.01 + 3.29) / 2 = **2.65.**

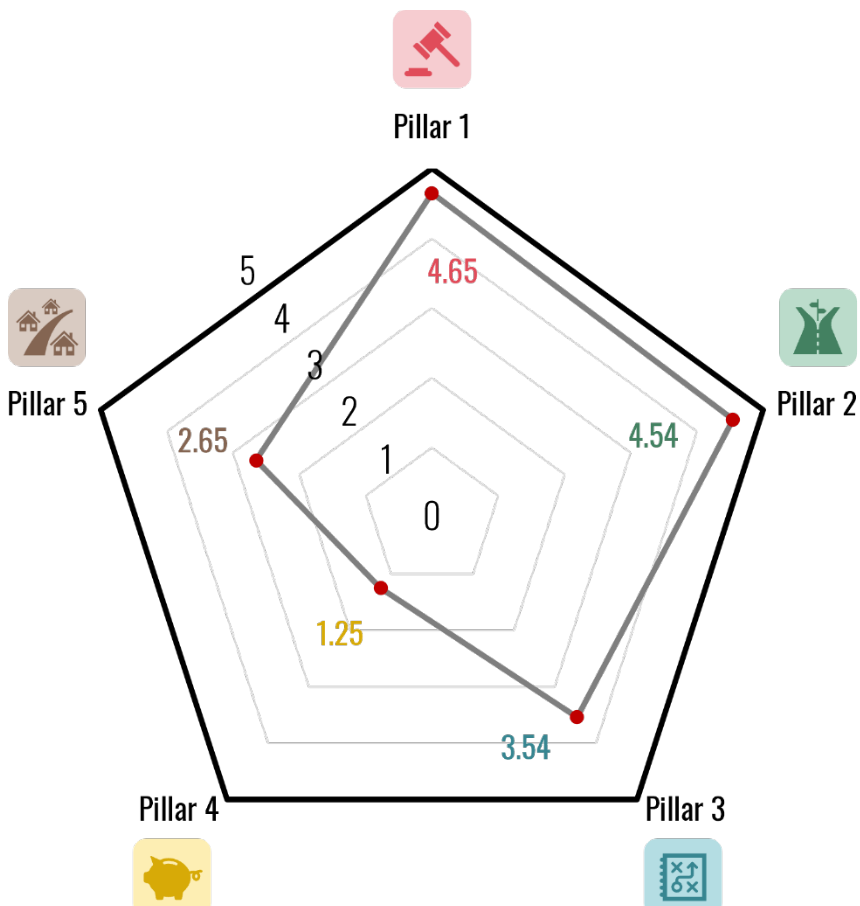
7. *Overall Score of Move Nona*

After holding several internal workshops and group discussions, the University of Florida research team presented the final pillar scores (criteria scores in parentheses) of Move Nona, summarized as follows (visualized in **Figures 8-6** and **8-7**):

1. Pillar 1 – Policy and Government Support: **4.65** (4.9 and 4.4)
2. Pillar 2 – Infrastructure and Technology: **4.54** (4.07 and 5)
3. Pillar 3 – Service and Management: **3.54** (2.88 and 4.2)
4. Pillar 4 – Financial Sustainability: **1.25** (2.5 and 0)
5. Pillar 5 – Ridership and Community Impact: **2.65** (2.01 and 3.29)

Figure 8-6

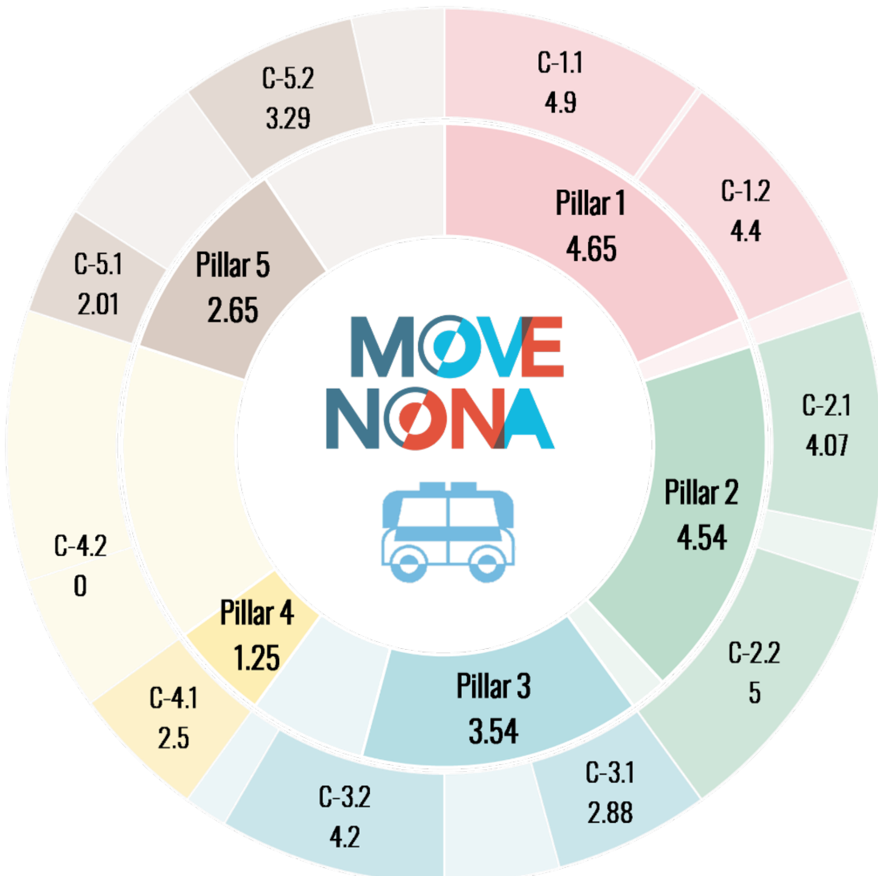
Move Nona's Effectiveness Score (Rader Chart Version)



Note. The radar chart shows the five pillar scores of Move Nona.

Figure 8-7

Move Nona's Effectiveness Score (Sunburst Chart)



Note. The sunburst chart represents the pillar and criteria scores of Move Nona. The outer ring shows the criteria scores, while the inner are pillar scores.

The pillars and criteria scores are numbers between zero to five. A higher score greater closer to 5 represents a more positive implication or better performance, worth promoting its experience. On the contrary, a pillar or criterion score lower than 2.5 implies the item has some flaws and possibly needs remedies. Through analyzing the scores, critical takeaways are as follows:

First, the high Pillar 1 score of 4.65 out of 5 (93 percent) suggests that Florida has been offering rich soil to fertilize the development of AV technology and AV-based microtransit systems. From the state level to the Lake Nona neighborhood, all levels of government have been actively preparing to automate its public transportation services by offering timely legislative support and convenient, professional administrative aids. In other words, new AV transportation solution providers/investors would receive the least resistance and restrictions in Florida. One suggestion is that other states or cities which are looking to implement AV transit services or attract investors should keep in line with Florida by referring to its AV-related laws, regulations, and plans and establish AV-related offices with specialists or leads. Another suggestion is that investors need to research and calculate the pillar score to find out if the state is inclined to support AV in general.

Second, Pillar 2 has a relatively high score, which is 4.54 out of 5, and the two criteria scores are 4.07 and 5. Criterion 2.1, targeting infrastructure readiness, indicates that Lake Nona's civil and transportation infrastructures and facilities are AV transportation friendly. For instance, the road size, pavement condition, and street signs only require minor modifications to accommodate an AV-based microtransit system, setting a good standard for other communities to match. The full score of Criterion 2.2 – quality of the AV shuttle model – recommends that new AV shuttle projects may consider employ models proven successful previously, such as the Navya Arma.

However, one limitation of the findings is that the circumstance of Lake Nona could not necessarily represent another region. Lake Nona is an expanding suburban neighborhood, which is distinctive from places like denser downtown areas, which are harder to modify roads and construct new AV facilities. Also, Lake Nona residents have much higher income and education levels than the rest of the city, and their perceptions and affordability of an AV transit system might be unique.

Third, Pillar 3 has a relatively low service quality score (2.88 out of 5) and a higher management quality score (4.2 out of 5) regarding Move Nona, resulting in a pillar score of 3.54 out of 5. The main culprit of the lower service score is that the speed of a Move Nona AV shuttle (less than 12.5 miles per hour) is much slower than the neighborhood's speed limit, extending the rider's travel time. Besides, as a demonstration project, its display value is somehow greater than its usefulness. Move Nona merely covers a small portion of the region, where riders cannot even ride the shuttle to the groceries right at the neighborhood's fringe. An additional issue is that the

AVs' lidars are sometimes too sensitive to avoid collisions, causing even minor objects like tree branches could cause the AVs to brake harshly, negatively affecting the AV's comfort score. We believe future projects with adequate funding could address those issues and improve AV shuttle performance. On the other hand, the higher management quality criterion score reflects BEEP's efforts in training employees and maintaining the entire system onsite and online, delineating the importance of owning a professional, dedicated operating team.

Fourth, Pillar 4 receives the lowest score among all pillars, which is 1.25, since Move Nona does not have any revenue sources other than solely relying on the continuous investment of Tavistock Development Company. We also estimated Move Nona's potential to become a long-term public transit option by comparing it with the city bus system. The finding was that AVs had a much higher cost per vehicle miles traveled, unveiling the problem that the price of the AV shuttle is too high. How much AVs can keep intriguing investors to pay and how long AVs can attract riders when they are no longer curious remain questionable.

Fifth, Pillar 5's score – 2.65 out of 5 – is not high because the criterion score of 5.1, the ridership impact of the AV service, is only 2.01. The main factor, again, is that Move Nona is not a full-scale public transportation service that focuses on shifting the residents' travel mode. It is impossible for Move Nona, which can only connect a few points of interest in the neighborhood, to motivate most residents to abandon driving private vehicles. At the same time, the other criterion score of the residents' perceptions and acceptance of Move Nona is 3.29, revealing a generally neutral to positive attitude towards the service, at least not antagonizing it. Hence, we are rather confident that future AV-based microtransit services can be popular among more residents in Lake Nona. The recommended approach is to target at the group working locally.

Chapter 9. Conclusions

By eyeing the benefits like high efficiency, low operation costs, and reduced car dependency, many studies have speculated how integrating an AV microtransit service into public transportation system could change communities and people's travel behaviors. However, it is impossible to anticipate these changes in the absence of a holistic matrix to describe and measure them, and so practitioners and decision-makers have been left in the dark over whether an AV microtransit service could be a panacea to transportation cruxes or useless. Given the financial and community losses at stake, the risk of implementing these services without a systematically designed matrix of measurements would be high. Therefore, building an AV Effectiveness Evaluation Framework has been paramount. The University of Florida (UF) research team, sponsored by FDOT, has proposed such an evaluative framework in this report.

Two primary contributions of this research were:

1. The UF team designed and constructed the Effectiveness Evaluation Framework of AV-based microtransit projects, known as the AVEE Framework. This framework was comprised of five pillars, 10 criteria, and 35 elements intended to measure political, technical, economic, and social implications and impacts holistically.
2. The UF team applied the AVEE Framework to the Move Nona AV shuttle program in Lake Nona, Orlando, FL, and documented the lessons learned from this application.

Other contributions of the research include:

1. The report provided an inventory of all operating AV shuttle programs in the United States and abroad, describing the most cutting-edge AV transit projects worldwide while drawing comparisons and contrasts between programs.
2. The report summarized the full scope of work of developing the AVEE Framework, consisting of the literature and publications the University of Florida team used as its intellectual foundations as well as how to utilize and critique those materials.
3. The report offered a user-friendly, step-by-step guide to applying the AVEE Framework, along with three customized versions to accommodate different users: AV readiness, vendor selection, and deployment evaluation.

4. The report demonstrated how obtain data and provided the procedures required to calculate each element scores to derive the project's overall score.
5. The UF team carried out a community survey and documented Lake Nona residents' perceptions of the AV shuttle service and their reasons for using (or not using) it.

Chapter 2's literature review identifies that most AV shuttle-based microtransit services today are pilot or demonstration programs. These programs use AVs predominantly manufactured by Navya, EasyMile, Local Motors, and Baidu. Those AVs could hold about eight to 15 people and run at a speed of 15 mph on a fixed route.

Using this information seized from the literature review, we analyzed publications such as the FDOT's CAV business plan, the AV Readiness Index from KPMG, and the UN-Habitat's SDG Assessment Tool in Chapter 3. We stepped on the shoulders of giants, reviewing and adopting applicable elements from each tool, including the structures, scoring metrics, measuring criteria, survey questions, and visual representations.

In Chapter 4, we explained how we created the AVEE Framework, how to use it, and who may use it. The scoring system of the AVEE Framework is a bottom-up, "element – criterion – pillar" approach on a zero to five scale. A score closer to 5 has a more positive implication, suggesting that the corresponding aspect of the AV project we are measuring performs well. The five pillars are Policy and Government Support, Infrastructure and Technology, Service and Management, Financial Sustainability, and Ridership and Community Impact. Users, including government officers, transportation experts, and an AV project's stakeholders, can grade the elements and aggregate the scores to obtain criterion and pillar scores.

In Chapter 5, we provided reasons for selecting Move Nona as our case study instead of the original target, the BUILD Grant project. The main reason was that the latter was still a proposal, which was not as valuable as studying an established, fully operational project, even though Move Nona has not benefited from the same range and magnitude of the BUILD Grant project, causing that some aspects of Move Nona have received lower scores in the assessment.

In Chapter 6, we analyzed Lake Nona's demographic characteristics, socio-economic and housing conditions, and the residents' travel patterns. The data suggests that Lake Nona has a higher white population (with Hispanic), income level, educational attainments, and housing prices compared with the rest of the city of Orlando. Besides, most people travel to work by private cars, whereas Lake Nona has no public transit system except the AV shuttles.

Chapter 7 depicts how the UF research team developed and deployed the Move Nona community survey. From the 223 responses, we learned that the sample's demographic features matched the overall population statistically. Then, the survey results proved that Lake Nona residents generally had positive views of the AV shuttle system, e.g., its safety and ease of use. Moreover, the survey respondents stated their expectations for the future AV transit system, including raising the speed and having a better smartphone app.

Finally, in Chapter 8, we applied the AVEE Framework in Chapter 8. Move Nona's pillar scores (out of 5) were as follows:

1. Pillar 1 – Policy and Government Support: **4.65**
2. Pillar 2 – Infrastructure and Technology: **4.54**
3. Pillar 3 – Service and Management: **3.54**
4. Pillar 4 – Financial Sustainability: **1.25**
5. Pillar 5 – Ridership and Community Impact: **2.65**

The first two scores mean that the state of Florida is ready for AV implementation, offering strong legislative, governmental, infrastructural, and technical support. The other relatively lower scores reveal two significant problems of the system: first, feedback on service operations suggested that many residents were not satisfied with the current speed of vehicle (12.5 mph) and with the shuttle's hard braking and the lack of sufficient route coverage. Second, it was difficult to assess the full picture of Move Nona's financial sustainability because it didn't charge the users. Nevertheless, the UF team estimated its annual operational cost and efficiency (passengers per VMT) and found that an AV shuttle would be more costly than a regular city bus mainly due to its high purchasing cost and low capacity and usage. Possible solutions to these issues, repeated throughout community survey responses, to attract more AV shuttle users are to at least increase the speed to 30 miles per hour and to promote Move Nona's smartphone app that displays the real-time map, schedules, and locations of all the shuttles. Should the roadway and passenger facilities proposed in the LAMN program be implemented, they may be able to help mitigate these concerns.

Additional takeaways obtained from the research and recommendations for people or government seeking experiences include:

1. Keeping an AV shuttle's speed of about 30 mph, promoting a smartphone app exhibiting real-time maps and schedules, adding more AV stops (or offering door-to-door service), and improving the smoothness of the ride may fulfill passengers' primary expectations.
2. According to Florida's experience, it is essential to have lucid, transparent transportation laws and regulations when promoting AV transit systems. Also, establishing a designated AV department or office may better enforce the implementation process.
3. New AV transit programs may consider using AV shuttles models that have been proven safe and reliable elsewhere, to avoid lengthy road/performance tests.
4. When selecting a site to accommodate an AV transit system, one should notice how much infrastructure modifications are required, e.g., expanding an extra lane will be lengthy and costly.
5. Some AV industry pioneers, like BEEP, have accumulated multiple years of experience of operating and maintaining the AV service, which can be shared with new AV operators.

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Appendix A. Move Nona Survey (Rider's Version)

University of Florida (UF) & Florida Department of Transportation (FDOT)

Welcome to the Move Nona Survey!

BEEP has started to provide autonomous shuttle services, i.e., Move Nona, for Lake Nona residents since 2019. It is an innovative approach to seeking future public transit options. Therefore, we are interested in understanding your experiences and opinions with these autonomous vehicles (AV), or self-driving cars. Your responses will be vital for us to learn the real impacts and effectiveness of the AV service here, which can further inform potential AV implementations nationwide.

Please refer to the table and figure below for definitions:

What is **BEEP**?	Beep is an autonomous mobility solutions provider of driverless shuttles and fully managed services based in Lake Nona.
What is an **Autonomous Vehicle** (AV)?	An autonomous vehicle (AV), also known as a driverless or self-driving vehicle, is an electric vehicle capable of sensing its environment and moving with little or no human input.
What is an **Autonomous Shuttle**?	A shuttle service operated by autonomous vehicles. Note that BEEP currently has an operator on board.

The Move Nona AV shuttle in Lake Nona

CONSENT FORM

You are invited to participate in a research study conducted by UF and FDOT. The purpose is to learn about your experiences and attitudes towards AV shuttles and the MOVE NONA service in Lake Nona.

This research is anonymous. Anonymous means that we will not record any information that could identify you, e.g., your name, address, phone number, date of birth, etc. There will be no linkage between your identity and your response. The research team and FDOT are the only parties allowed to see the data, except as may be required by law. We will only state group results if this study report is published or presented at a professional conference. There are no foreseeable risks to taking part in this study. In addition, you may receive no direct benefit from participating in this study. Participation in this study is voluntary. You may choose not to participate and withdraw at any time of the study procedures without penalty. In addition, you may choose not to answer any questions with which you are not comfortable.

This survey will take about **4** to **10** minutes. If you are 18 years of age or older, understand the statements above, and will consent to participate in the study, select "I Agree" to begin the survey. If not, select "I Do Not Agree" to leave.

☐ I Agree (Please continue to the survey)
☐ I Do Not Agree

Please indicate your opinion (from "Very Disagree" to "Very Agree") on the statements below by checking the box. If you are unsure or the question is not applicable, please leave it blank.

	Very Disagree	Disagree	Neutral	Agree	Very Agree
1.1 If I want to use the AV shuttle, I think it will be **easy** for me (Even if I haven't used it before).	☐	☐	☐	☐	☐
1.2 If I want to use the AV shuttle, it will **not** require a lot of mental effort (even if I haven't used it before).	☐	☐	☐	☐	☐
1.3 If I want to use the AV shuttle, my interaction with it will be straightforward and understandable.	☐	☐	☐	☐	☐
1.4 I think the AV shuttle can let me get to my destination **faster** (if within its service area).	☐	☐	☐	☐	☐
1.5 I think the AV shuttle can let me get around **easier** (if within its service area).	☐	☐	☐	☐	☐
1.6 I think the AV shuttle is a **useful** transportation method (if within its service area).	☐	☐	☐	☐	☐
1.7 I have used or have planned to use the AV shuttle.	☐	☐	☐	☐	☐
1.8 If the AV shuttle can reach my destination, I think I will use it.	☐	☐	☐	☐	☐
1.9 If the AV shuttle can reach my destination, it can encourage me to travel more frequently.	☐	☐	☐	☐	☐
1.10 As a driver, I think driving near an AV shuttle is safe.	☐	☐	☐	☐	☐
1.11 I think walking or riding a bike near an AV shuttle is safe.	☐	☐	☐	☐	☐
1.12 I am comfortable with my children (age 12 - 18) using AV shuttles.	☐	☐	☐	☐	☐
1.13 If the AV shuttle's speed increased from 15 mph (now) to 30 mph, I think walking/biking near it would be **safe**.	☐	☐	☐	☐	☐
1.14 I think riding in an AV shuttle is **not safe** in windy or rainy weather.	☐	☐	☐	☐	☐
1.15 I think the AV shuttles may **not perform well** and cause problems to my trips in windy or rainy weather.	☐	☐	☐	☐	☐
1.16 If I must travel in windy or rainy weather, I **cannot** rely on AV shuttles.	☐	☐	☐	☐	☐
1.17 I think having an AV shuttle service can make a neighborhood more attractive.	☐	☐	☐	☐	☐
1.18 If I wanted to choose where to live in the future, having an AV shuttle service would positively influence my decision.	☐	☐	☐	☐	☐
1.19 The Move Nona AV service was a factor that I decided to live in Lake Nona.	☐	☐	☐	☐	☐
1.20 In general, I like to try new technology/products.	☐	☐	☐	☐	☐
1.21 If I hear about a new technology/product, I want to try or experiment with it.	☐	☐	☐	☐	☐
1.22 I am usually the **first** to try out a new technology/product among my peers.	☐	☐	☐	☐	☐
1.23 I consider my actions' potential **environmental impact** when making many decisions.	☐	☐	☐	☐	☐
1.24 I am willing to take more environmentally friendly actions even if they are less convenient.	☐	☐	☐	☐	☐
1.25 I am concerned about issues like air pollution, waste of resources, and climate change.	☐	☐	☐	☐	☐

2.1 Please indicate your **gender**:

☐ Male ☐ Female ☐ Prefer not to answer ☐ Other: _______

2.2 Please indicate your **age**:

☐ 18 – 24 ☐ 25 – 34 ☐ 35 – 44 ☐ 45 – 54 ☐ 55 – 64 ☐ 65 – 74 ☐ 75 and over

2.3 Please indicate your **race/ethnicity** (select all that apply):

☐ Asian/Pacific Islander ☐ Black/African American ☐ White ☐ Hispanic/Latino ☐ Other: _______

2.4 Please indicate your highest level of **education** you have completed:

☐ Below high school ☐ High school graduate/GED ☐ Some college, no degree ☐ Associate degree
☐ Bachelor's degree ☐ Master's degree or higher ☐ Prefer not to answer ☐ Other: ________

2.5 Please indicate your current **employment** status:

☐ Work Part-time ☐ Work Full-time ☐ Self-employed ☐ Not employed
☐ Retired ☐ Full-time Student ☐ Prefer not to answer ☐ Other: ________

2.6 Please indicate your estimated annual **household income:**

☐ Under $25,000 ☐ $25,000 – $49,999 ☐ $5,0000 – $74,999 ☐ $75,000 – $99,999
☐ $100,000 – $149,000 ☐ $150,000 or more ☐ Prefer not to answer ☐ Other: ________

2.7 Please indicate where you **work** apart from Lake Nona:

☐ Within 2 miles ☐ Within 2 to 10 miles ☐ Within 11 to 25 miles ☐ Over 25 miles

2.8 In a typical week, what is your primary means of **transportation** for work?

☐ Drive ☐ Bus ☐ Rideshare (e.g., carpool) ☐ Bike
☐ Walk ☐ AV shuttle ☐ Work from home / not currently working ☐ Other: ________

2.9 Do you own a working motor vehicle, such as a car, truck, or motorcycle?

☐ Yes ☐ No ☐ Prefer not to answer

2.10 How long does it take for you to **walk** to the nearest AV stop from home?

☐ Less than 5 minutes ☐ 5 to 10 minutes ☐ 10 to 15 minutes ☐ More than 15 minutes

2.11 What is the maximum **distance** that you are willing travel to an AV stop from home/work?

☐ Less than 1/4 mile ☐ 1/4 to 1/2 mile ☐ 1/2 to 1 mile ☐ 1 mile and more ☐ Other: _______

2.12 What is the maximum time that you are willing to **wait** for an AV shuttle?

☐ At most 5 minutes ☐ At most 10 minutes ☐ At most 15 minutes ☐ Other: _______

2.13 Please indicate the features/services that will encourage you to use an AV shuttle (select all that apply):

☐ I can hail and ride the AV shuttle from anywhere along its route ☐ Increase the AV's speed
☐ I can get off the AV shuttle anywhere along its route ☐ Increase the shuttle frequency
☐ Broader service area ☐ Offer free Wi-Fi on-board ☐ Offer free Wi-Fi at AV stops
☐ A smartphone app that shows real-time location of the shuttles ☐ More AV stops
☐ Better exterior and interior design of the AV shuttles ☐ Provide parking facilities for bikes
☐ Other (please specify):

3.1 In the past year, approximately **how many times** have you ridden the Move Nona AV shuttle? (Note: getting on and off an AV once counts as one ride.)

☐ More than 20 times ☐ 10 to 20 times ☐ 3 to 10 times ☐ Less than 3 times

3.2 On average in the past year, **how often** did you ride the Move Nona AV shuttle?

☐ At least once per week ☐ At least once per month ☐ Less than once per month

3.3 Do you have a fixed **routine** or schedule of riding the Move Nona AV shuttle?

☐ Yes ☐ No

3.4 What was the primary **destination** of using the Move Nona AV shuttle?

☐ Work
☐ Leisure (dining out, shopping, social activities, etc.)
☐ Connecting to another mode of transportation
☐ No specific destination (e.g., just to experience the AV)

3.5 What are some reasons that you chose to use the Move Nona AV shuttle over another mode of travel (e.g., driving, walking, biking, etc.)? Select all that apply:

☐ Curious to try new technology
☐ It is more convenient
☐ It is more enjoyable
☐ It is more comfortable
☐ It is free
☐ It is safer
☐ I don't want to drive within my neighborhood
☐ I don't have a private vehicle
☐ Parking is difficult at my destination
☐ It protects the environment
☐ Other (please specify): ________

Please indicate your opinion (from "Very Disagree" to "Very Agree") on the statements below by **checking** the box. If you are unsure or the question is not applicable, please leave it blank.

	Very Disagree	Disagree	Neutral	Agree	Very Agree
3.6 I think the design of the Move Nona AV (e.g., door size and step height) make it **easy** for me to get on and off.	☐	☐	☐	☐	☐
3.7 I think the **cabin size** of the Move Nona AV is spacious.	☐	☐	☐	☐	☐
3.8 I think the Move Nona AV's **seats** are comfortable.	☐	☐	☐	☐	☐
3.9 When I am taking a ride in the Move Nona AV, I feel that its **movement** is as smooth as a regular vehicle's.	☐	☐	☐	☐	☐
3.10 When I am taking a ride in the Move Nona AV, I think the **noise level** is finely controlled.	☐	☐	☐	☐	☐
3.11 When I am taking a ride in the Move Nona AV, I think it is as **safe** as using a regular vehicle.	☐	☐	☐	☐	☐
3.12 If the AV shuttle's speed increased from 15 mph (now) to 30 mph, I think riding in it would be **safe**.	☐	☐	☐	☐	☐
3.13 Overall, I think most of my **expectations** towards AV shuttles are confirmed.	☐	☐	☐	☐	☐
3.14 I think my experience with the Move Nona AV shuttle was **better** than what I expected.	☐	☐	☐	☐	☐
3.15 I **enjoy** taking a ride in a Move Nona AV shuttle.	☐	☐	☐	☐	☐
3.16 I am **satisfied** with the Move Nona AV shuttle system.	☐	☐	☐	☐	☐

Please use the back of the page if you have any other comments about the Move Nona AV shuttle.

Appendix B. Move Nona Survey (Non-Rider's Version)

University of Florida (UF) & Florida Department of Transportation (FDOT)

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CONSENT FORM

You are invited to participate in a research study conducted by UF and FDOT. The purpose is to learn about your experiences and attitudes towards AV shuttles and the MOVE NONA service in Lake Nona.

This research is anonymous. Anonymous means that we will not record any information that could identify you, e.g., your name, address, phone number, date of birth, etc. There will be no linkage between your identity and your response. The research team and FDOT are the only parties allowed to see the data, except as may be required by law. We will only state group results if this study report is published or presented at a professional conference. There are no foreseeable risks to taking part in this study. In addition, you may receive no direct benefit from participating in this study. Participation in this study is voluntary. You may choose not to participate and withdraw at any time of the study procedures without penalty. In addition, you may choose not to answer any questions with which you are not comfortable.

This survey will take about **4** to **10** minutes. If you are 18 years of age or older, understand the statements above, and will consent to participate in the study, select "I Agree" to begin the survey. If not, select "I Do Not Agree" to leave.

☐ I Agree (Please continue to the survey)
☐ I Do Not Agree

Please indicate your opinion (from “Very Disagree” to “Very Agree”) on the statements below by checking the box. If you are unsure or the question is not applicable, please leave it blank.

	Very Disagree	Disagree	Neutral	Agree	Very Agree
1.1 If I want to use the AV shuttle, I think it will be **easy** for me (Even if I haven’t used it before).	☐	☐	☐	☐	☐
1.2 If I want to use the AV shuttle, it will **not** require a lot of mental effort (even if I haven’t used it before).	☐	☐	☐	☐	☐
1.3 If I want to use the AV shuttle, my interaction with it will be straightforward and understandable.	☐	☐	☐	☐	☐
1.4 I think the AV shuttle can let me get to my destination **faster** (if within its service area).	☐	☐	☐	☐	☐
1.5 I think the AV shuttle can let me get around **easier** (if within its service area).	☐	☐	☐	☐	☐
1.6 I think the AV shuttle is a **useful** transportation method (if within its service area).	☐	☐	☐	☐	☐
1.7 I have used or have planned to use the AV shuttle.	☐	☐	☐	☐	☐
1.8 If the AV shuttle can reach my destination, I think I will use it.	☐	☐	☐	☐	☐
1.9 If the AV shuttle can reach my destination, it can encourage me to travel more frequently.	☐	☐	☐	☐	☐
1.10 As a driver, I think driving near an AV shuttle is safe.	☐	☐	☐	☐	☐
1.11 I think walking or riding a bike near an AV shuttle is safe.	☐	☐	☐	☐	☐
1.12 I am comfortable with my children (age 12 - 18) using AV shuttles.	☐	☐	☐	☐	☐
1.13 If the AV shuttle’s speed increased from 15 mph (now) to 30 mph, I think walking/biking near it would be **safe**.	☐	☐	☐	☐	☐
1.14 I think riding in an AV shuttle is **not safe** in windy or rainy weather.	☐	☐	☐	☐	☐
1.15 I think the AV shuttles may **not perform well** and cause problems to my trips in windy or rainy weather.	☐	☐	☐	☐	☐
1.16 If I must travel in windy or rainy weather, I **cannot** rely on AV shuttles.	☐	☐	☐	☐	☐
1.17 I think having an AV shuttle service can make a neighborhood more attractive.	☐	☐	☐	☐	☐
1.18 If I wanted to choose where to live in the future, having an AV shuttle service would positively influence my decision.	☐	☐	☐	☐	☐
1.19 The Move Nona AV service was a factor that I decided to live in Lake Nona.	☐	☐	☐	☐	☐
1.20 In general, I like to try new technology/products.	☐	☐	☐	☐	☐
1.21 If I hear about a new technology/product, I want to try or experiment with it.	☐	☐	☐	☐	☐
1.22 I am usually the **first** to try out a new technology/product among my peers.	☐	☐	☐	☐	☐
1.23 I consider my actions’ potential **environmental impact** when making many decisions.	☐	☐	☐	☐	☐
1.24 I am willing to take more environmentally friendly actions even if they are less convenient.	☐	☐	☐	☐	☐
1.25 I am concerned about issues like air pollution, waste of resources, and climate change.	☐	☐	☐	☐	☐

2.1 Please indicate your **gender**:

☐ Male ☐ Female ☐ Prefer not to answer ☐ Other: _______

2.2 Please indicate your **age**:

☐ 18 – 24 ☐ 25 – 34 ☐ 35 – 44 ☐ 45 – 54 ☐ 55 – 64 ☐ 65 – 74 ☐ 75 and over

2.3 Please indicate your **race/ethnicity** (select all that apply):

☐ Asian/Pacific Islander ☐ Black/African American ☐ White ☐ Hispanic/Latino ☐ Other: _______

2.4 Please indicate your highest level of **education** you have completed:

☐ Below high school ☐ High school graduate/GED ☐ Some college, no degree ☐ Associate degree
☐ Bachelor's degree ☐ Master's degree or higher ☐ Prefer not to answer ☐ Other: ________

2.5 Please indicate your current **employment** status:

☐ Work Part-time ☐ Work Full-time ☐ Self-employed ☐ Not employed
☐ Retired ☐ Full-time Student ☐ Prefer not to answer ☐ Other: ________

2.6 Please indicate your estimated annual **household income:**

☐ Under $25,000 ☐ $25,000 – $49,999 ☐ $5,0000 – $74,999 ☐ $75,000 – $99,999
☐ $100,000 – $149,000 ☐ $150,000 or more ☐ Prefer not to answer ☐ Other: ________

2.7 Please indicate where you **work** apart from Lake Nona:

☐ Within 2 miles ☐ Within 2 to 10 miles ☐ Within 11 to 25 miles ☐ Over 25 miles

2.8 In a typical week, what is your primary means of **transportation** for work?

☐ Drive ☐ Bus ☐ Rideshare (e.g., carpool) ☐ Bike
☐ Walk ☐ AV shuttle ☐ Work from home / not currently working ☐ Other: ________

2.9 Do you own a working motor vehicle, such as a car, truck, or motorcycle?

☐ Yes ☐ No ☐ Prefer not to answer

2.10 How long does it take for you to **walk** to the nearest AV stop from home?

☐ Less than 5 minutes ☐ 5 to 10 minutes ☐ 10 to 15 minutes ☐ More than 15 minutes

2.11 What is the maximum **distance** that you are willing travel to an AV stop from home/work?

☐ Less than 1/4 mile ☐ 1/4 to 1/2 mile ☐ 1/2 to 1 mile ☐ 1 mile and more ☐ Other: _______

2.12 What is the maximum time that you are willing to **wait** for an AV shuttle?

☐ At most 5 minutes ☐ At most 10 minutes ☐ At most 15 minutes ☐ Other: _______

2.13 Please indicate the features/services that will encourage you to use an AV shuttle (select all that apply):

☐ I can hail and ride the AV shuttle from anywhere along its route ☐ Increase the AV's speed
☐ I can get off the AV shuttle anywhere along its route ☐ Increase the shuttle frequency
☐ Broader service area ☐ Offer free Wi-Fi on-board ☐ Offer free Wi-Fi at AV stops
☐ A smartphone app that shows real-time location of the shuttles ☐ More AV stops
☐ Better exterior and interior design of the AV shuttles ☐ Provide parking facilities for bikes
☐ Other (please specify):

3.1 Please indicate the reason(s) that you **haven't** used the BEEP AV shuttle in Lake Nona (select all that apply):

- ☐ I don't know about the AV program in Lake Nona
- ☐ I am not interested in this new transportation system
- ☐ I think this new system might be confusing/complicated to use
- ☐ I am satisfied with my current travel modes
- ☐ I have safety concerns with the system
- ☐ The AVs are not attractive
- ☐ The AVs are too slow
- ☐ The operating hours are limited/not convenient
- ☐ The shuttles are not frequent enough
- ☐ The stops are too far from where I want to start and end my trip
- ☐ The destinations are limited shuttle does not serve areas I travel to
- ☐ Other (please specify below): ________

Please use the space below if you have any other comments about the Move Nona AV shuttle.