Sawgrass Mills Mall Area Autonomous Vehicle (AV) Shuttle Feasibility Assessment

CITY OF SUNRISE MOBILITY HUB STUDY

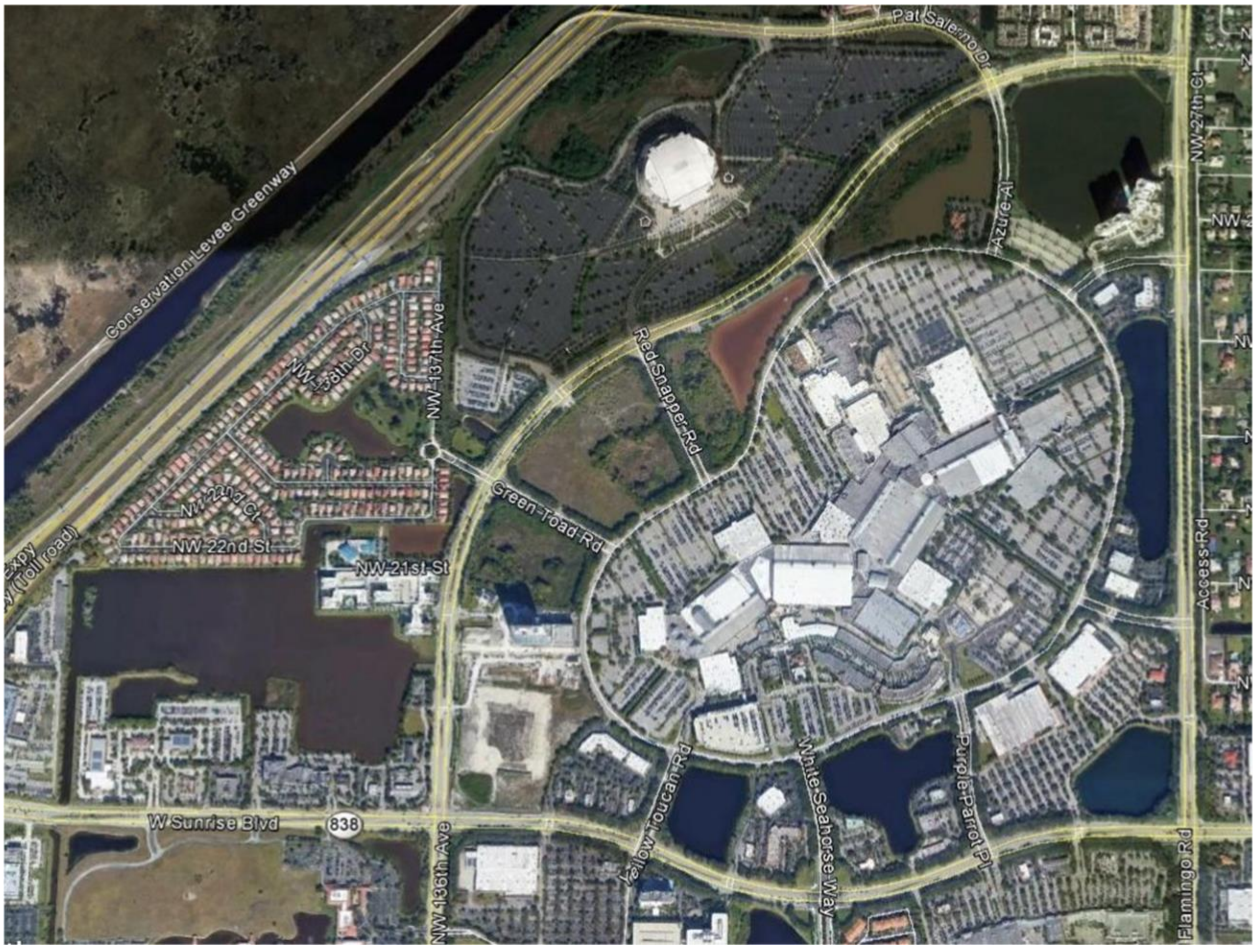
Broward MPO
Metropolitan Planning Organization

Contents

ASSESSMENT PURPOSE

The purpose of this assessment is to evaluate the feasibility of utilizing AV shuttles to help address the growing mobility needs in the western Sunrise area near the Sawgrass Mills Mall (Figure 1) in concert with the Broward County Metropolitan Planning Organization's (MPO's) Mobility Hub Master Plan. This includes evaluating different AV operational scenarios that factor the performance capabilities of current AV vehicles on the market, service and routing options with associated fleet requirements, and infrastructure needs to support Broward County's MPO's mobility objectives.

FIGURE 1: SAWGRASS MILLS MALL AREA



AV ASSESSMENT OBJECTIVES

This AV assessment will define applicable performance measures based on area travel characteristics, evaluate AV transit vehicle options, and identify a likely range of project costs. If deemed feasible, the mobility evaluation will serve to:

- Establish transit and infrastructure needs for a project steering committee,
- Introduce and test AV technology safely in a targeted area,
- Provide first mile/last mile mobility between transit stations, commercial areas, and potential residential areas, and

- Meet current regulatory requirements for AV operations in Florida.

In addition to assessing how AVs can address mobility needs for the Sawgrass Mills Mall area, this assessment can also serve to provide information for other mobility options in the region that may require similar community circulator or similar first mile/last mile mobility needs.

AV FEASIBILITY ASSESSMENT

Defining Project Performance Measures

To determine the feasibility of a proposed improvement, it is important to understand what measures should be used to define successful operations and whether the project can achieve these performance goals. This project is unique in that performance measures can evaluate both the success of serving a mobility need and the operations of a new and emerging transportation technology (autonomous driving systems).

Potential mobility performance measures are provided in Table 1 below. These do not include all performance measures traditionally associated with a fixed route or on-demand transit service, but rather focus on those performance measures that can be specifically applied to serving a mobility need around a large commercial establishment such as the Sawgrass Mills Mall.

Potential AV performance measures are provided in Table 2. These performance measures can be used to evaluate the feasibility of utilizing AV technology for this specific type of mobility application. These can also be applied to other mobility needs throughout the region that have similar operating domains.

TABLE 1: POTENTIAL AV TRANSIT MOBILITY PERFORMANCE MEASURES

Performance Metric	Justification
Survey response of riders using AV shuttle	Surveys will help understand rider's willingness to utilize AV shuttles as a part of their travel and mobility needs.
Number of bicycles on board the AV shuttle	The ability of accommodating bicycles will allow for multi-modal transportation planning for improved mobility.
Number of riders	Ridership will measure the AV route's ability to address mobility needs.
Number of transfers	Number of transfers will measure rider's willingness to utilize AVs for first mile/last mile transportation.
Average Travel Speed	The AV vehicle's capabilities should match that of other vehicle operating speeds.
Vehicle/Person Delay	The AV operations plan should provide an opportunity to limit vehicle or person delay.
Level of Service	The available system should provide an adequate level of service to be an attractive mode of travel for choice riders.

TABLE 2: POTENTIAL AV SYSTEM PERFORMANCE MEASURES

Performance Metric	Justification
Number of preventable crashes	Understanding the ability of AVs to avoid preventable crashes can build trust in the AV operating system.
Percent of time during operating hours the system shut down due to operating system security breaches	Deploying secure AV systems is critical for potential multiple deployments and efficient operations.
Number or rate of AV system disengagements due to operating system malfunction, unknown action, or vehicle capabilities	Deploying reliable AV systems is critical for potential multiple deployments and efficient AV operations.
Accuracy and timeliness of data reported on operations and performance	Efficient data reporting allows AV travel planning decisions to be made in near real-time.
On-time performance	Deploying reliable AV vehicles and AV systems is critical for potential multiple deployments and serving the needs of the Sawgrass Mills Mall area.
Missed hours of operation due to equipment breakdown	Deploying reliable AV vehicles is critical for efficient operations and serving the needs of the Sawgrass Mills Mall area.

Addressing Area Travel Needs

To determine the mobility need, understanding current and future travel characteristics is critical. It is recommended that data be used to determine origin-destinations, dwell times, and predictable travel patterns between residential, commercial, and employment nodes to determine the potential customer base, market capture, and most effective routes to serve mobility needs. The current challenge in the Sawgrass Mills Mall area is the ongoing evolution and densification of the development pattern, with a lack of accurate and current data available to provide an appropriate analysis. An analysis and deployment of local connectivity services will be more time once a couple of pending planned developments occur that will both boost and alter traffic patterns.

Identifying transit potential for both captive and choice riders would be ideal. Data collected can be used for determining:

- The duration and volume of trips to key activity centers from the study area,
- Common drop-off and pick-up locations for effective route planning,
- The circuity of routes in the study area,
- Alternative modes and network improvements for the most congested routes,
- Travel patterns, origins, and destinations at every street and intersection, and
- The unique behaviors, patterns, and activities of vehicles including commercial trucks.

Understanding travel patterns will be essential in matching the type of AV transit vehicle to be used for the potential deployment. For example, travel patterns that are only intended on serving destinations along low speed routes, such as the mall circulator road can be served by multiple types of AV transit vehicles. Whereas, routes that involve travel on higher speed roadways may be better served by retrofitting existing vehicles. The differences in vehicle capabilities is described within the *Evaluation of Autonomous Transit Vehicles* section of this report.

Providing Desired Levels of Service

The services provided and operations of any AV program need to be developed with partners, stakeholders, and local businesses to address the project goals. With the project area centered around the Sawgrass Mill Mall and BB&T Arena, local commercial establishment business hours and event schedules will drive the hours of operation considerations and peak hour needs. The evolving nature of development in the area and potential changes at the BB&T Arena site present a challenge, as they will impact service needs in ways impossible to anticipate today.

> TO PROVIDE OPPORTUNITIES FOR MALL WORKERS TO UTILIZE THE SYSTEM BEFORE AND AFTER MALL OPERATING HOURS, AND TO ACCOMMODATE LATE NIGHT USAGE DURING ARENA EVENTS, OPERATING HOURS FOR THE SHUTTLE WILL NEED TO BE BETWEEN 14 -16 HOURS EACH DAY.

Feedback can be incorporated into a Concept of Operations (ConOps) document that will detail the operating parameters and operating design domain for the AV deployment. This ConOps should be included in the Request for Proposal packet, which allows interested vendors to accurately estimate the time and materials necessary to deliver the mobility service. It is recommended that the vehicles remain staffed as a part of an AV Operational Deployment Plan in order to monitor fleet operations performance and software, conduct customer surveys if desired, and provide regular status reports. Detailed operational planning should also be required to be provided by the interested vendors to include details on the management of the fleet regarding procedures for starting daily AV service, recharging activities, and maintenance and storage of AVs.

Achieving Stakeholder Requirements

It will be important to involve potential stakeholders early in order to build consensus on identifying mobility needs and feasibility success measures. It is recommended that an outreach plan be developed for the introduction of new routes, technology, and AV shuttles. Certain AV capabilities may require use of connected vehicle (CAV) technologies that would require coordination and permitting to install and modify local and state agency resources, such as traffic signals. This specialized equipment can be used for communications to vehicles, technology to monitor location and status, and changes in roadway elements to allow for stop locations and facilities.

> ESTABLISHING A STEERING COMMITTEE AND HAVING A LOCAL CHAMPION CAN ASSIST WITH IMPORTANT OUTREACH ACTIVITIES AND AGENCY COORDINATION IN ORDER TO ALIGN THE PROJECT WITH MEASURES OF SUCCESS FOR DIVERSE STAKEHOLDER INTEREST.

Mobility Hub master planning includes the following stakeholders: Broward MPO; Broward County Transit; Broward County Planning; Broward County Highway Construction and Engineering; Broward County Traffic Engineering; the Florida Department of Transportation District Four; the City of Sunrise; and local businesses and commercial establishments. Coordination and buy in from these stakeholders can provide increased ridership through improved project awareness as well as funding opportunities through vehicle advertisements.

EVALUATION OF AUTONOMOUS VEHICLES

In order to determine the success of an AV vehicle for transit and mobility services, it is important to align the capabilities and requirements of the AV systems against the needs of patrons (i.e. capacity, bike storage, ADA accessibility, passenger comfort) and services being proposed. Low speed AV vehicles, higher speed AV vehicles, and EV modified buses are discussed below.

LOW SPEED AV VEHICLES

Most AVs have very low maximum speeds when compared to typical vehicles and buses. Typical AV speeds are 10 to 25 mph when in AV operational mode. The lower speeds are for several reasons, including the type of drive train used to keep vehicle capital costs down, safety of passengers that may be standing, data processing using technology to monitor the vehicle track, the objects around it, the interactions of the patrons, and communications with roadside and central monitoring systems.

Most low speed AV vehicles are defined by five characteristics:

> ANY VEHICLE WITHOUT A STEERING WHEEL, ACCELERATION AND BRAKING PEDALS, AND REARVIEW MIRRORS OPERATING ON A PUBLIC ROAD WOULD REQUIRE A FEDERAL EXEMPTION, WHICH MAY TAKE MONTHS TO ACQUIRE.

- Square-box-on-wheels appearance (see Figure 2),
- Can accommodate approximately six to 12 passengers in a combination of standing and seated configurations,
- Provide a spot for a safety driver or concierge,
- Utilize an electric power train, and
- Do not comply with current Federal Motor Vehicle Safety Standards (no steering wheels, rearview mirrors, etc..

AVs use of electric drive systems can provide unique challenges. The biggest challenge is battery life and the need to recharge. Charging requirements and the desire to constantly monitor AV performance are two primary reasons that AV vehicles are used in defined environments with fixed route deployments of limited route length that remain close to recharging stations. In south Florida's hot environment where air conditioning is needed, battery capacity will be less than optimal based on operational needs beyond propulsion and braking.

FIGURE 2: EASY MILE LOW SPEED AV SHUTTLE

Another common trait of low-speed AV shuttles is that they do not have On-Board Units (OBUs) that communicate with Roadside Units (RSUs) in order to appropriately react to a signal system. In some cases, this is due to the signal system not having the required infrastructure. Therefore, most deployments have required an attendant to remain on board to navigate through signal controlled and stop sign controlled intersections.

Case Study: Denver

The EasyMile shuttle is highlighted in Figure 2 as an example from its recent six month pilot in Denver (http://www.rtd-denver.com/61AV.shtml) that ended August 2, 2019. The shuttle used in the Denver pilot had a passenger capacity of 12 with seating for six and operational speeds along a fixed route of approximately 10 to 12 mph. Additional findings of the Denver Pilot are set to be officially released in Fall 2019.

Although the EasyMile Shuttle utilized in the Denver Pilot can operate completely autonomously, the pilot project chose to keep a representative on board in case of any situation that arose that required a driver to take over control for operation. This person was referred to as an "Ambassador" that typically provided information and general assistance to patrons. Table 3 indicates the Easy Mile Shuttle (EZ10) specifications used in the Denver pilot project.

TABLE 3: EASY MILE SHUTTLE (EZ10) SPECIFICATIONS

Passenger capacity per vehicle	Up to 15 passengers
Disabled access	Built-in automated electric access ramp
Service operation modes	Scheduled (fixed route, network) or On-demand
Fleet management system	Fleet
Weather conditions	Heavy rain, snow, fog, temperature from - 15°C to 45°C / -5 to 115°F
Net vehicle weight	2,130 kg (4 battery packs and enhanced A/C)
Gross Vehicle Weight (GVW)	3,130 kg (4 battery packs and enhanced A/C)
Dimensions (LxWxH)	13'-3.5" x 6'-2.5" x 9' – 5"
Minimum turning radius	5 m
Energy	Electric (Battery type LiFePo4)
Battery capacity	30.72 kWh
Vehicle Range	up to 16 hours
Charging time	6 hours
Direction	Unidirectional
Max. speed	28 mph, electronically limited to 15.5 mph
Max. slope	15% @ GVW
Connectivity	GSM/ EDGE/ UMTS/ LTE modem
Vehicle to Everything (V2X) module	Optional
Wireless charger	Optional
Passenger counter	Optional

Case Study: New York City

Another example of a shuttle program is in New York City (Figure 3). This AV shuttle pilot, which recently began, is referred to as Optimus Ride. It has very similar characteristics to the Denver AV pilot, providing a fixed route shuttle service. A description of the project can be found at the following link: https://www.digitaltrends.com/cars/optimus-ride-to-offer-autonomous-shuttle-rides-in-new-york-city/

Low Speed AV Vendor Key Features

The following items should be considered as criteria when comparing low speed AV vendors.

1) AV vendor history
2) AV availability
3) Drive train – Electric/Hybrid
4) Operational run time
5) Recharge time
6) Operational speed in autonomous mode
7) Patron capacity total and seated
8) Fleet Management Software Systems
9) Wheelchair accessible – ADA compliant
10) Connected Vehicle Integration
    a) On board unit/roadside unit (OBU/RSU)
11) Available features:
    a) Heat/Air Conditioning
    b) Internal camera for monitoring patrons
    c) External cameras for monitoring vehicles
    d) Video recording of cameras and continuous recording time

FIGURE 3: NEW YORK CITY AV SHUTTLE DEPLOYMENT

A full list of AV shuttles and their comparisons can be found in the **Appendix: Automated Shuttle Vendor Matrix**.

HIGHER SPEED AV VEHICLES

EV Modified Shuttle

For higher speed service options using AV shuttles, current efforts in the industry are focused on repurposing and utilizing traditional transit vehicles. Much of this work is being done to add autonomous features to existing vans and buses. While there are instances of "driverless" vehicles, many of the modifications are more in line with "Pilot Assist" to provide more safety features, and other technology changes such as electric, alternative, or hybrid fuel options.

Perrone Robotics is an example of one company that is automating Ford Transit Vans (as in Figure 4 below) and starting to add other larger full-size buses to their mobility fleets.

FIGURE 4: REPURPOSED FORD TRANSIT VAN BY PERRONE ROBOTICS

The electric vehicle (EV) version of this vehicle has a 60- or 120-mile range depending on the battery and drive system deployed. While a gasoline powered version has just over a 500-mile range with a 25-gallon tank. These vehicles are less focused on self-driving in an uncontrolled environment, and more on using technology to increase safety. The added safety can also be considered a cost saving strategy, as the added safety features can reduce incidents that result in capitol repair costs and costs associated with patron injuries.

These vehicles also provide an alternative to AV vehicles where traffic patterns, roadway speeds, roadway characteristics, and where flexible routes may create challenges for AVs. Since these vehicles utilize already approved USDOT vehicle specifications, no exemptions are needed to begin operations.

SINCE THE MODIFIED BUSES HAVE VEHICLE SHAPES SIMILAR TO WHAT IS SEEN ON THE ROAD TODAY, THE PUBLIC PROFILE OF THE AV PILOT PROJECT WILL NOT BE AS READILY EVIDENT. PUBLIC NOTIFICATIONS, SUCH AS VEHICLE WRAPS AND OTHER MARKETING, WILL BE NEEDED TO ADVERTISE THE UNIQUE FEATURES OF THE AV PILOT PROJECTS.

EV Modified Bus

Larger buses are being retrofitted with automated technologies and electric power trains as well. Although there are few instances to site as an example, Volvo is looking to start a fleet of such buses, however deployment is likely years away.[1]

AV SHUTTLE COSTS

It is important to note that AV Shuttle project costs can greatly vary. This is especially true regarding pilot projects where AV vendors may provide their costs as a direct vehicle cost, but on others provide the vehicles, monitoring and fleet management as a service fee. In many cases for pilot projects, the vehicle costs have been partly to fully absorbed as an in-kind service or as contribution by the project's partnerships.

[1] https://www.metro-magazine.com/technology/news/733266/volvo-unveils-world-s-first-full-size-autonomous-electric-bus

There are other potential costs associated with AV shuttle projects beyond vehicle capital costs. For instance, if the AV pilot project is also connected to the signal systems, additional investments associated with infrastructure upgrades for communications and monitoring, such as RSUs and OBUs will be required. Additional costs can include roadway improvements with signage, pullover lanes for stops, shuttle stop facilities, charging stations, and storage.

Project costs can also include staff and marketing costs. Staff are needed to monitor and manage the fleet management software, and even though the vehicles are autonomous, most AV pilot projects still maintain a person on board the vehicle to help manage unexpected situations.

THE BUDGET FOR THE SIX (6) MONTH DENVER SHUTTLE 61AV PROJECT WAS APPROXIMATELY $170,000. HOWEVER, ALL STAFF TIME FOR THE PROJECT WAS PROVIDED AS IN-KIND CONTRIBUTION FROM THE PROJECT PARTNERS. ADDITIONAL OUT OF POCKET COSTS WERE APPROXIMATELY $16,000 FOR REGULATORY SIGNAGE/INSTALLATION AND A PORTION OF THAT ALSO CONTRIBUTING TO ONGOING O&M COSTS.

The following costs provided in this section are general assessment estimates, which are based on experiences with similar projects and technologies and should only be used to provide discussion on the magnitude of costs. Budgetary estimates should be developed as high-level concepts, designs, and requirements of a program are developed.

AV Shuttles

Most pilot projects have seen the capital cost of AV shuttles being between $200k - $350k per year with the lower cost per vehicle associated with deployments longer than one year. This cost can vary based upon whether the vehicle is purchased or leased and what equipment is required to be on the vehicle such as OBUs or automated ramps. If purchased, the O&M cost of the shuttle can range between $20k and $40k per year with an additional fee of around $50k for mapping and route testing. The AV comparisons in the Appendix provides additional cost information.

Additional AV Shuttle Features

Connected Systems

Connected signal system costs could include signal integration for Signal Phase and Timing (SPaT) messages, signal timing and preemption options, broadcasting safety messages from emergency vehicles, bicycle and pedestrian warning systems, and monitoring of routes with closed circuit television (CCTV). Costs, which depend on choices and specific design could range from $50k to $100k per intersection or up to $250k per centerline mile in the covered route.

Whether the communications systems uses 4G or 5G cellular, or fiber to support dedicated short-range communications (DSRC), the costs can be $10k - $50k per vehicle and up to $200k - $250k per centerline mile for either poles and antennas to support cellular or fiber-based communications.

Operations and Maintenance (O&M)

O&M costs can vary dramatically depending on the procurement type utilized and where the responsibility lies. For leased vehicles, maintenance costs can be included in the bid package. Likewise, with most vehicles being driven by electric systems, the costs to charge can also be the responsibility of the owner/operator.

Since this project is a unique transit deployment within Broward County, an AV fleet management system will be needed. It should be expected that, at a minimum, the license for a commercial-off-the-shelf (COTS) package could cost around $100k. More customized packages with complex management features, on-demand capabilities could require up to several million dollars.

Operations staff needed for monitoring, dispatch, route management, safety, maintenance activities, and concierge or ambassador services can also be required to be included within the bid package. These costs should be planned based on Broward County Transit's (BCT's) current costs for staff.

AV Shuttle Stations

Providing kiosks for the stops could be expected to be approximately $100k per kiosk. Providing content for the kiosk will entail additional costs and could be part of a COTS vendor package or require development.

Table 4 provides a summary of AV deployment costs.

TABLE 4: SUMMARY OF POTENTIAL AV SHUTTLE COSTS

Line Item	Assumptions	Potential Cost
Vehicles	Leased vehicle	$300k / vehicle / year
Signal Communication Systems	DSRC at signals	$100k / signal
Fleet Management System	No on-demand services or flexible routes	$100k
Stations	Real-time, interactive displays at each kiosk	$100k / kiosk
Operations Staff	Consistent with avg. BCT costs/operating hour	TBD

ASSESSMENT OF ROUTES

One of the basic determinations of routes will be the type of service provided. Determining whether to provide an on-demand, flexible route model or a fixed-route model is critical. Providing on-demand services introduces additional software, security, and operational requirements and costs. With both first mile/last mile and AV service being new to the area, it will be easier to introduce, market and clearly inform the public and potential patrons of the new mobility options. Therefore, it is recommended that the initial pilot project be a fixed route system. As noted previously however, it is premature to consider identifying a fixed route yet, with the ongoing development and unknown future of the BB&T Arena.

Recommendations to follow in this report assume a fixed route option that does not provide on-demand services.

ROUTE CONSIDERATION CRITERIA FOR AV SHUTTLES

This assessment identifies several criteria that should be considered when developing a proposed AV shuttle route. With AV shuttles, the route needs to consider the limits of any potential shuttle, the roadway characteristics; the potential location and frequency of stops; and safety concerns. The following is a limited list of criteria when considering an AV shuttle route:

1. Desired service area
2. Desired services to provide
3. Current services available or planned, including by others
4. AV Shuttle limitations:
    a. Speed of AV in operation
    b. Operational limit – battery life
    c. Passenger capacity
    d. Special needs access
5. Roadway Characteristics
    a. Lanes of roadway
    b. Posted speeds
    c. Type of roadways of route and route intersections
    d. Intersection control (signals, stop signs, roundabouts)
    e. Availability for stop locations
6. Expected/desired number of stops
7. Designation of points/stops
8. Locations for AV storage, maintenance, or recharging stations
9. Expected number of AVs in the fleet
10. Communication needs
11. AV support structure – V2X, dedicated short-range communications (DSRC), etc.
12. The ability to provide ADA access for patrons

EXAMPLE RECOMMENDED AV DEPLOYMENT PLAN AND ROUTE

Based on current AV vehicle capabilities, the transit service market, and service options compatible with existing transit services, the following represents an example AV deployment and route description. This example provides one option that could be used to address the region's mobility needs. Additional stakeholder input and understanding of the future development pattern will be needed to refine these recommendations. Figure 5 illustrates options that include:

1. Use current BCT transit as is, but reduce the pickup and drop-offs in the target area:
    a. Pickup/Stop at Green Toad Road Transit Station, in lieu of directly serving the mall property
2. Use higher speed EV buses for routes that go beyond Sawgrass Mills Circle
    a. Pickup/Stops include
        i. Metropica's Masterplan Diagrams Option B Stops
        ii. Green Toad Road Transit Station
        iii. American Express
        iv. Uber Lot
        v. Three Mall Stops
3. Use low-speed AV shuttles for Commercial Areas
    a. Pickup/Stops Include:
        i. Green Toad Road Transit Station
        ii. Nine Loop Stops (Parking Locations)
        iii. Three Mall Stops

FIGURE 5: EXAMPLE AV / EV TRANSIT ROUTES

Information from this AV feasibility assessment can be used to identify items requiring further development for the AV Deployment Plan (AVDP). The AVDP will further refine expected costs based on a Concept of Operations, AV fleet requirements, partner participation, funding mechanisms, and needed facilities and infrastructure improvements. The AVDP will also identify anticipated roles of project agencies, task leads, program partners, project stakeholders, operation and maintenance (O&M) procedures, and any marketing plans.

CONCLUSIONS AND RECOMMENDED NEXT STEPS

This assessment provides high-level information on AV shuttle capabilities, potential route strategies, and generalized AV capital and operational costs. Going forward, it will be necessary for distinct and measurable goals to be established for the AV transit project in order to define a successful operating plan, as the capabilities, service characteristics, and customer perceptions of low speed and higher speed AV vehicles are different. As noted previously, the Sawgrass Mills Mall area is not yet ready for effective deployment of AV shuttles due to the rapid ongoing evolution of AV technologies, the evolving nature of mobility needs in the area, and the need for physical upgrades to both the mall ring road and NW 136th Avenue at a minimum to accommodate the specialized vehicles.

After additional development has occurred, a long-term strategy for a proposed light rail extension to the area is better understood, and a long-term strategy for the potential re-use of the BB&T Center property comes into focus, an analysis of new traffic patterns and the potential for alternative and/or autonomous mobility services should be undertaken.

There are several recommendations that apply to any eventual operating scenario. These include:

- Identify a local champion to help develop public enthusiasm for the safety and mobility improvements the project offers the Sunrise area and throughout other similar areas in the region.
- Establish a steering committee to coordinate with the public and stakeholders, develop project goals, objectives, performance measures, and marketing materials, make decisions on AV planning, and coordinate with design consultants and developers.
- Develop a Concept of Operations document for the AV program.
- Gather detailed origin-destination, travel pattern, and dwell time data so that AV transit stations can be placed in opportune locations. With the area potentially undergoing future development/redevelopment efforts, understanding potential changes in travel demand and future travel patterns will be necessary for long-term success.
- Develop an outreach campaign to let area residents, visitors, businesses, and workers become aware of the availability of the technology and benefit opportunities, while also establishing expectations on the technology capabilities.
- Maintain a concierge or ambassador on board to survey passengers about their perceptions and experience utilizing the technology in order to develop effective outreach campaigns in the future. A concierge or ambassador will also be able to regain control of the vehicle if the operating system is unsure of what actions to take or to navigate through signal-controlled intersections if the intersections are not equipped with appropriate RSUs to communicate with the vehicle, or if the vehicle is not equipped with an appropriate OBU.
- Work with local signal maintaining agencies to develop an RSU plan so that signal information can be transferred to the vehicle operating system, allowing for maximum autonomous operations.

For low speed vehicle operations:

- Limit operations to the ring road around the mall, parking areas, and side streets around the mall. This will provide the safest operational environment as operational speeds will be comparable to other vehicle operating speeds.
- If operations only take place on private facilities such as the parking lot or ring road around the mall (if not a local road), federal exemptions will not be needed, allowing for earlier deployments.

For higher speed (retrofitted) vehicles:

- Operations can take place within and around the mall and surrounding community.
- Additional project branding and outreach activities will be required as the vehicle type is common to the area, so it will not be obvious from initial appearance that the vehicle is autonomous. A vehicle wrap may be a cost-effective way to address this issue.

APPENDIX: AUTOMATED SHUTTLE VENDOR MATRIX

Automated Shuttle Vendors							
	Coast Automation	EZMile	2GetThere	Mobility Cubed (World Bus)	Local Motors	May Mobility	Ohmio
Website	http://www.coastautonomous.com	http://easymile.com/	www.2getthere.eu	http://www.mobilitycubed.net	https://localmotors.com	www.maymobility.com	www.ohmio.com
Contact	Adrian Sussman 404.641.1365 asussmann@coastautonomous.com	Joseph Holmes 303 881 3883 joseph.holmes@easymile.com	Wessel van der Pol wessel@2getthere.eu	Mike Gerard (503) 781-9634 info@www.mobilitycubed.net	Brad Rutherford (865) 249-8280 brutherford@localmotors.com	Alisyn Malek 313.374.8886 alisyn.malek@maymobility.com	Mr. Dean Zabrieszach dean.zabrieszach@hmitechnologies.com.au 61-409-144-647
Location	Apasadena, CA	Denver, CO	Neatherlands	Vancover, WA	Tempe, AZ, Knoxville, TN, National Harbor, MD	Michigan	New Zealand, Australia, China, Taiwan, United Kingdom
Vehicle Types	20 passenger shuttle	12 passenger shuttle, developing 40ft bus Inveco, Airport GSE Vehicles	4 passenger shuttle, 12 passenger shuttle, and 24 passenger shuttle w/ Central Control similar to APM	16 passenger shuttle	12 passengers, smaller, larger and cargo models coming	6 passenger open shuttle (They use the Polaris Gem vehicle)	All vehicles are modular and customisable
Deployments	Demos provided in Tampa	85+ vehicles including Minnesota All Weather Testbed and Denver, CO Pena station connection.	10+ Systems with multiple vehciles including Schiphol Airport's long term parking lot	Hong Kong Airport, Disney and Portland are potential	NY University Buffalo	3 test pilots, Michigan, Florida, and Texas	Urban, Rural, Campus, Precinct Seamless Indoor/Outdoor Transition, all environments all weather conditions and operational temperature ranges above -15 degrees centigrade
Sensor Technology	LIDAR. Cameras, Odometer, V2V and V2I CV	LIDAR, Cameras, Radar, GPS, V2V & V2I CV	LIDAR, Camera and Magnetic pavement	LIDAR, radar, sonic, stereo cameras (Urban Systems in integrator)	LIDAR, Camera, radar, ultrasonic, V2V & V2I coming	LIDAR, Radar, IR, Camera	Optical, LIDAR, radar, GNSS GPS and in-house telemetry developments.
Routing Options	Fixed Route w deviation, working on on-demand	Fixed Route w deviation & on-demand	Fixed Route with deviation	Fixed Route, working on on-demand	Fixed route and on-demand	Fixed route circulator, on-demand next year	Fixed and Dynamic – Virtual Tracks L4+ Technology
Accessibility	Electric ADA ramp	Electric ADA Ramp	Electric ADA Ramp	Currently working on issue	Prototype ADA vehicle	No ramp currently	Wheel Chair Ramp standard, Braille, Hearing Aid Loops, PA systems, tactile surfaces, kneeling systems, grab handles
Operating Speed	<20mph around objects, 50mph max for vehicle up to 60mph in software	12mph normal around people, 30mph max	35mph max	Under 25mph, normally 8-15mph, 35 mph max	25mph max		Configurable depending on operational scenario requirements, safety regulations and legislation
Directionality	Bi-directional	Bi-directional	One directional (15m turn)	One directional	One directional now (18 ft)	One direction	Bi-directional
Operation Time on Full Charge	10 hours w/ battery, 24/7 operation with super capacitors	9 hours w/AC, 15 hours wo/AC	>50km	40 miles wo/AC	4 hours, 10 hours coming	3 hours	All products are designed to charge whilst in use if operating in 24 hour use mode. In other modes battery pack sizes vary.
Charging Time	4 hours battery, 5 minutes super capacitor	4.5 hours	4-5 hours	2 hour (Working on 30 minutes)	4.5 hours	1 hour	All products are designed to charge whilst operating.
Lease Cost (Includes monitoring and maitnenace)	$120k per year per vehicle	$132k per year per vehicle	No	Not available	$175K per year ($12-16k per month)	Annual operating agreement $125K per year per vehicle for at least 5 vehicles	Not available.
Insurance	Customer to obtain ($2k per month)	Included in lease	N/A	Customer to obtain ($2k per month)	Included with lease	Included with annual operating agreement	Operational insurances are to be carried by the Customer unless under a full managed service.
Purchase Cost	$200K + annual O&M	$235K + 5% O&M annual	Requires full system starting at $1M+	$225k + license and service agreement	$350K	N/A	N/A
Delivery	3 months from contract	3 months from signing	No demos, require full system deployment	10-11 months	12 months due to approval	6-12 months	3-4 months

REFERENCES

AV VENDOR LINKS

Automated Shuttle Vendors	Reference
Coast Autonomous	http://www.coastautonomous.com
Local Motors - Olli	www.localmotors.com
EzMile – Ez-10	http://easymile.com/
CityMobil2	www.citimobil2.eu
Transdev	www.transdev.com
May Mobility	www.maymobility.com
Softbank Drive	https://www.softbank.jp/en/drive/
Ohmio	https://ohmio.com/
Auro Robotics	http://auro.ai/
Polaris	https://www.youtube.com/watch?v=Y0N8zdijxGs
MobilityCubed - Worldbus	http://www.mobilitycubed.net/#section-our-outstanding-service
OptimusRide	https://www.optimusride.com/about
Toyota ePalette	https://www.youtube.com/watch?v=XbL33BKReHE
2GetThere – GRTs	www.2getthere.eu
Mercedes Future Bus	https://www.daimler.com/innovation/autonomous-driving/future-bus.html